

PROCEEDINGS
OF
THE PHYSICAL SOCIETY
OF LONDON.

JULY 1878.

XXVII. *On the Physical Action of the Microphone.*

By Professor HUGHES.*

In the paper read on the 9th of May before the Royal Society, I gave a general outline of the discoveries I had made, the materials used, and the forms of microphone employed in demonstrating important points. I have made a great number of microphones, each for some special purpose, varying in form, mechanical arrangement, and materials. It would require too much time to describe even a few of them; and as I am anxious in this paper to confine myself to general considerations, I will take it for granted that some of the forms of instrument and the results produced are already known.

The problem which the microphone solves is this—To introduce into an electrical circuit an electrical resistance, which resistance shall vary in exact accord with sonorous vibrations so as to produce an undulatory current of electricity from a constant source, whose wave-length, height, and form shall be an exact representation of the sonorous waves. In the microphone we have an electric conducting material susceptible of being influenced by sonorous vibrations; and thus we have the first step of the problem.

The second step is one of the highest importance: it is essential that the electrical current flowing be thrown into waves of determinate form by the sole action of the sonorous vibra-

* Read June 8, 1878.

tions. I resolved this by the discovery that when an electric conducting matter in a divided state, either in the form of powder, filings, or surfaces, is put under a certain slight pressure, far less than that which would produce cohesion and more than would allow it to be separated by sonorous vibrations, the following state of things occurs. The molecules at these surfaces being in a comparatively free state, although electrically joined, do of themselves so arrange their form, their number in contact, or their pressure (by increased size or orbit of revolution) that the increase and decrease of electrical resistance of the circuit is altered in a very remarkable manner, so much so as to be almost fabulous.

The problem being solved, it is only necessary to observe certain general considerations to produce an endless variety of microphones, each having a special range of resistance.

The tramp of a fly or the cry of an insect requires little range but great sensitiveness; and two surfaces, therefore, of chosen materials under a very slight pressure, such as the mere weight of a small superposed conductor, suffice; but it would be unsuitable for a man's voice, as the vibrations would be too powerful, and would, in fact, go so far beyond the legitimate range that interruptions of contact amounting to the well-known "make and break" would be produced.

A man's voice requires four surfaces of pine charcoal, as is described in my paper to the Royal Society, six of willow charcoal, eight of boxwood, and ten of gas-carbon. The effects, however, are far superior with the four of pine than with either the ten of gas-carbon or any other material as yet used. It should be noted that pine wood is the best resonant material we possess; and it preserves its structure and quality when converted into the peculiar charcoal I have discovered and described.

It is not only necessary to vary the number of surfaces and materials in accordance with the range and power of the vibrations, but these surfaces and materials must be put under more or less pressure in accordance with the force of the sonorous vibrations. Thus for a man's voice the surfaces must be under a far greater pressure than for the movements of insects. Still the range of useful effect is very great, as the boxes which I have specially arranged for man's voice are still sensitive to the tick of a watch.

In all cases it should be so arranged that a perfect undulatory current is obtained from the sonorous vibrations of a certain range. Thus, when speaking to a microphone transmitter of human speech, a galvanometer should be placed in the circuit, and, while speaking, the needle should not be deflected, as the waves of + and - electricity are equal, and are too rapid to disturb the needle, which can only indicate a general weakening or strengthening of the current. If the pressure on the materials is not sufficient, we shall have a constant succession of interruptions of contact, and the galvanometer-needle will indicate the fact. If the pressure on the materials is gradually increased, the tones will be loud but wanting in distinctness, the galvanometer indicating interruptions; as the pressure is still increased, the tone becomes clearer, and the galvanometer will be stationary when a maximum of loudness and clearness is attained. If the pressure be further increased, the sounds become weaker though very clear; and as the pressure is still further augmented the sounds die out (as if the speaker were talking and walking away at the same time) until a point is arrived at where there is complete silence.

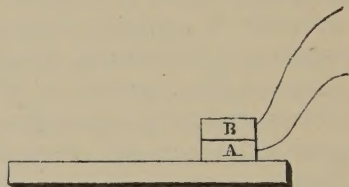
When the microphone is fixed to a resonant board, the lower contact should be fixed to the board, so that the sonorous vibrations act directly on it. The upper contact, where the pressure is applied, should be as free as possible from the influence of the vibrations, except those directly transmitted to it by the surfaces underneath; it (the upper surface) should have its inertia supplemented by that of a balanced weight. This inertia I find necessary to keep the contact unbroken by powerful vibrations. No spring can supply the required inertia; but an adjustable spring may be used to ensure that the comparatively heavy lever shall duly press on the contacts.

The superposed surfaces in contact may be screwed down by an insulated screw passing through them all, thus doing away with the lever and spring; but this arrangement is far more difficult to adjust, and the expansion by heat of the screw causes a varying pressure. It is exceedingly simple, however, easily made, and illustrates the theoretical conditions better than the balanced lever I have adopted in practice.

In order to study the theoretical considerations, and that with

the most simple form of microphone freed from all surrounding mechanisms, let us take a flat piece of charcoal 2 millims. thick and 1 centim. square, and, after making electrical contact by means of a copper wire on the lower surface, glue that to a small resonant board or, better for the purpose of observation, to a block of wood 10 centims. square. Upon this superpose one or more similar blocks of charcoal, the upper surface in communication with a wire, the lowermost surface resting flat, or as nearly so as possible, on the lower block.

The required pressure is put on the upper block; and while in this state the two may be fastened together with glue at the sides, or, better, by an insulated screw. The pressure can then be removed, as the screw or glue equally preserves the



force. Let the lower piece be called A and the upper B: when we subject this board to sonorous vibrations, we cannot imagine an undulatory movement of the actual wave-length in such a mass, that is a length comparable with the real wave-length of the sonorous wave, which may be several feet. Nor can we imagine a wave of any length without admitting that the force must be transmitted from molecule to molecule throughout the entire length: thus any portion of a wave, of which this block represents a fraction, must be in molecular activity. The lower portion of the charcoal A, being part of the block itself, has this molecular action throughout, transmitting it also to the upper block. How is it that the molecular action at the surfaces of A and B should so vary the conductivity or electrical resistance as to throw it into waves in the exact form of the sonorous vibrations? It cannot be because it throws up the upper portion, making an intermittent current, because the upper portion is fastened to the lower, and the galvanometer does not indicate any interruption of current whatever. It cannot be because the molecules arrange themselves in stratified lines, becoming more or less conductive, as then surfaces would not be required—that is, we should not require discontinuity between

the blocks A and B; nor would the upper surface be thrown up if the pressure be removed, as sand is on a vibrating glass. The throwing-up of this upper piece B when pressure is removed proves that a blow, pressure, or upheaval of the lower portion takes place: that this takes place there cannot be any doubt, as the surface, considered alone (having no depth), could not bodily quit its mass. In fact, there must have been a movement to a certain depth; and I am inclined to believe, from numerous experiments, that the whole block increases and diminishes in size at all points, in the centre as well as the surface, exactly in accordance with the form of the sonorous wave. Confining our attention, however, to points on A and B, how can this increased molecular size or form produce a change in the electrical waves? This may happen in two ways:—*first*, by increased pressure on the upper surface, due to its enlargement; or, *second*, the molecules themselves, finding a certain resistance opposed to their upward movement, spread themselves, making innumerable fresh points of contact. Thus an undulatory current would appear to be produced by infinite change in the number of fresh contacts. I am inclined to believe that both actions occur: but the latter seems to me the true explanation; for if the first were alone true, we should have a far greater effect from metal powder, carbon, or some elastic conductor, such as metallized silk, than from gold or other hard unoxidizable matter; but as the best results as regards the human voice were obtained from two surfaces of solid gold, I am inclined to view with more favour the idea that an infinite variety of fresh contacts brought into play by the molecular pressure affords the true explanation. It has the advantage of being supported by the numerous forms of microphone I have constructed, in all of which I can fully trace the effect.

I have been very much struck by the great mechanical force exerted by this uprising of the molecules under sonorous vibrations. With vibrations from a musical box 2 feet in length, I found that one ounce of lead was not sufficient on a surface of contact 1 centim. square to maintain constant contact; and it was only by removing the musical box to a distance of several feet that I was enabled to preserve continuity of current with a moderate pressure. I have spoken to forty

microphones at once ; and they all seemed to respond with equal force. Of course there must be a loss of energy in the conversion of molecular vibrations into electrical waves ; but it is so small that I have never been able to measure it with the simple appliances at my disposal. I have examined every portion of my room—wood, stone, metal, in fact all parts—and even a piece of india-rubber : all were in molecular movement whenever I spoke. As yet I have found no such insulator for sound as gutta-percha is for electricity. Caoutchouc seems to be the best ; but I have never been able by the use of any amount at my disposal to prevent the microphone reporting all it heard.

The question of insulation has now become one of necessity, as the microphone has opened to us a world of sounds, of the existence of which we were unaware. If we can insulate the instrument so as to direct its powers on any single object, as at present I am able to do on a moving fly, it will be possible to investigate that object undisturbed by the pandemonium of sounds which at present the microphone reveals where we thought complete silence prevailed.

I have recently made the following curious observation :—A microphone on a resonant board is placed in a battery-circuit together with two telephones. When one of these is placed on the resonant board, a continuous sound will emanate from the other. The sound is started by the vibration which is imparted to the board when the telephone is placed on it ; this impulse, passing through the microphone, sets both telephone-disks in motion ; and the instrument on the board, reacting through the microphone, causes a continuous sound to be produced, which is permanent so long as the independent current of electricity is maintained through the microphone. It follows that the question of providing a *relay* for the human voice in telephony is thus solved.

The transmission of sound through the microphone is perfectly duplex ; for if two correspondents use microphones as transmitters and telephones as receivers, each can hear the other, but his own speech is inaudible ; and if each sing a different note, no chord is heard. The experiments on the deaf have proved that they can be made to hear the tick of a watch, but not, as yet, human speech distinctly ; and my results in

Fig. 1.

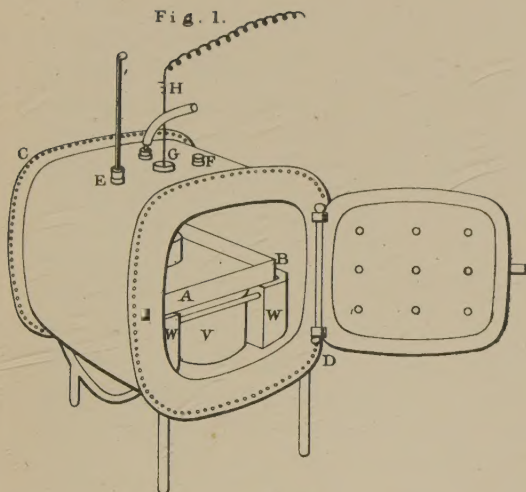


Fig. 2.

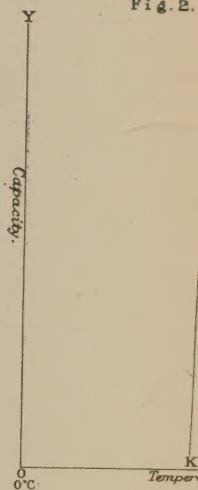


Fig. 4.

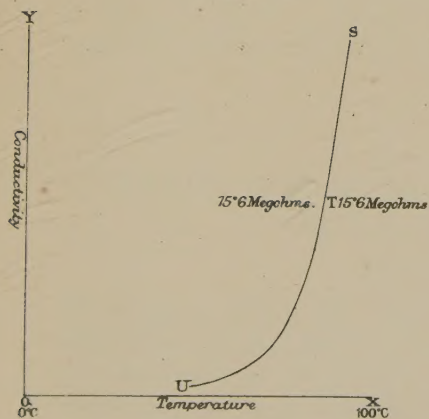
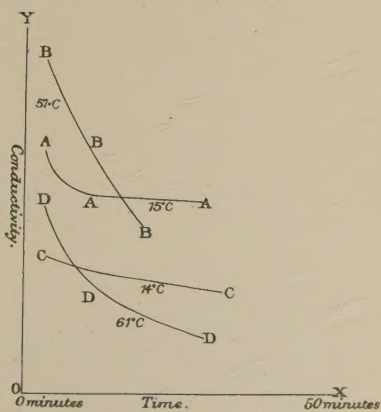
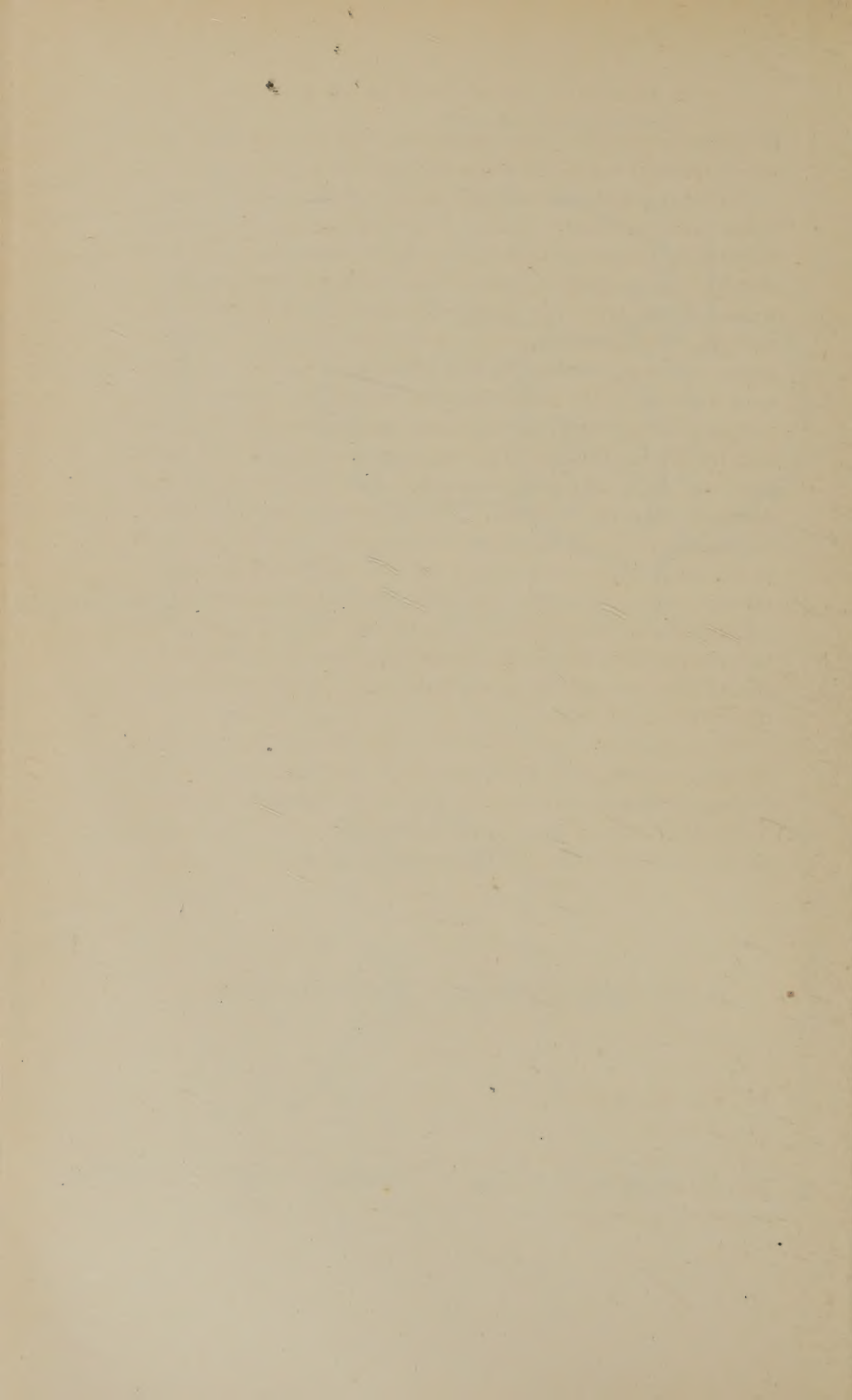


Fig. 5.





this direction point to the conclusion that we only hear ourselves speak through the bones and not through the ears.

However simple the microphone may appear at first glance, it has taken me many months of unremitting labour and study to bring to its present state through the numerous forms each suitable for a special object. The field of usefulness for it widens every day. Sir Henry Thompson has succeeded in applying it to surgical operations of great delicacy; and by its means splinters, bullets, in fact all foreign matter, can be at once detected. Dr. Richardson and myself have been experimenting in lung- and heart-diseases; and although the application by Sir H. Thompson is more successful, I do not doubt that we shall ultimately succeed. There is also hope that deafness may be relieved. For telephony articulation has become perfect, and the loudness increased. Duplex and multiplex telegraphy will profit by its use; and there is hardly a science, where acoustics has any direct or indirect relation, which will not be benefited. And I feel happy in being able to present this paper on the results obtained by a purely physical action to such an appropriate and appreciative body as the Physical Society.

In conclusion, allow me to state that throughout the whole of my investigations I have used Prof. Bell's wonderfully sensitive telephone instrument as a receiver, and that it is owing to the discovery of so admirable an appliance that I have been enabled to commence and follow up my researches.

XXVIII. *On Brass Wind Instruments as Resonators.*

By D. J. BLAIKLEY*.

[Plate VI.]

IN bringing before the Physical Society a few notes and experiments on this subject, I would desire to say that they are the result of an attempt to carry somewhat more into detail than, as far as I am aware, has hitherto been done, some acoustical investigations of the late Sir C. Wheatstone. A

* Read May 25, 1878.

most interesting paper on Wheatstone's work in this field was brought before the Musical Association by Professor W. G. Adams in 1876; and to that paper I am in great measure indebted.

A brass instrument may be defined as a resonator capable of reinforcing a certain fundamental periodic vibration originated by the lips, and all such vibrations as have for their relative numbers 2, 3, 4, &c. when the fundamental note is represented by unity,—these vibrational numbers being the basis of what is known as the natural harmonic series of musical intervals—and this series being the same, whatever may be the absolute pitch of the fundamental note or the character of tone of the instrument.

It is possible to make the lips give notes which, although scarcely audible, are of definite pitch, without the use of an instrument, just as a tuning-fork gives its proper note with or without a resonator.

There are two simple forms of resonators which give the series of notes required in wind instruments: these are the open tube of equal section throughout, and the cone complete to its apex, where it is of course closed. In the tube the wave-length of any note is inversely proportional to its vibrational number; and the nodes or points of maximum compression and rarefaction, and the centres of the ventral segments, or points of maximum amplitude of vibration are equidistant: but in the cone this is not the case. Wheatstone found experimentally that the notes of a closed cone agree in pitch with those of an open tube of the same length; and therefore the prime or fundamental tone of such a cone is an octave higher than the prime of a closed tube of the same length. He found also that in conic frustra of similar lengths, but of different proportions as regards the diameters of their ends, the pitch varied, rising as the difference between the two ends increased when the small end was closed, and becoming lower under the same conditions when the large end was closed. The accompanying diagram (Plate VI.) shows the positions of the nodes and centres of ventral segments in an open tube and a cone of the same length for the notes c , c' , g' , c'' , marked 1, 2, 3, 4 (c having 128 vib., and a wave-length of 105 in. at 60° F.). The numerals grouped together and marked N show the positions of the

nodal points or surfaces, and those marked $\frac{V.S}{2}$ the centres of the ventral segments or points of maximum vibration. The effect that the diminishing size of the cone has upon the position of the nodes may be easily traced. Whilst the positions of the centres of the ventral segments remain the same as in the open tube (the numerals for these on the cone in the diagram falling exactly under those for the open tube), the nodes are gradually further and further apart, dividing their respective ventral segments more and more unequally, until at the apex of the cone is a node common to all the notes. It follows from this that the centre of a ventral segment in a cone is not the centre of the length between its nodes, and, conversely, that as the diameters of the two ends of the ventral segment approach equality, so does the position of the node become more central, until the condition of vibration existing in an open cylindrical tube is reached; and such a tube may evidently be considered as a portion of a cone whose apex is at an infinite distance. It is to be noticed that in the cone the number of $\frac{1}{4}$ wave-lengths, or semi-ventral segments, is not directly proportional to the vibrational number as in the open tube, but, with the exception of the fundamental note, is always in excess. Thus let

$$N = \text{number of } \frac{1}{4} \text{ wave-lengths,}$$

$$n = \text{relative vibrational number;}$$

then

$$N = n + (n-1) = 2n-1.$$

Instances.—Note 1 (fundamental) $N = 1 + (1-1) = 1$,

Note 4 (double octave) $N = 4 + (4-1) = 7$.

The velocity of the portion of wave or waves in the cone therefore differs with the pitch of the note, and is in no case the same as the velocity in free space. Assuming this latter to be 1120 feet per second, we should have in the cone the following velocities:—

Note.		n .	N .	Feet per second.
<i>c</i>	128	 1	1	2240
<i>c'</i>	256	 2	3	1493·4
<i>g'</i>	384	 3	5	1344
<i>c''</i>	512	 4	7	1280

and the space traversed by the waves of the different notes in one second, measuring from the apex of the cone to, say, the ear of an observer:—

<i>c</i>	128	.....	1122·1875	feet.
<i>c'</i>	256	.....	1121·0937	„
<i>g'</i>	384	.....	1120·7292	„
<i>c''</i>	512	.....	1120·5468	„

The method I used to find the positions of the nodal points in the cone, and which is applicable to wind instruments or tubes of any varying section, may be illustrated by a conic frustum open at both ends. Holding a vibrating fork over one end (in this case *c* 512), gradually sink the tube in water: the water-level when the tube is giving its maximum resonance shows the position of the node.

Brass instruments are generally considered to be cones, or cones combined with cylindrical tubing, neither of which descriptions properly applies; and this I will endeavour to make clear by experiment. We may, in the first place, consider whether the resonance of cones and tubing is influenced appreciably by the action of the lips; and it will be found that, whether the lips or a tuning-fork be used to excite the vibration, the pitch is the same. Two illustrations may be given—the first a common hunting-horn, pitch *c* 512 when it is blown, and giving an excellent resonance to the *c* 512 fork when the mouthpiece is closed; if, however, we slightly alter its length either way, the resonance to the fork is no longer at its maximum. For the second illustration, I take a cylindrical tube which becomes closed on being placed against the lips: blowing it as a wind instrument, we find its proper tones are *c* 128, *g'* 384, *e''* 640, *b''* 896, &c., the same as it would give as a resonator, and that the pitch of these tones is so definite that it is very difficult to alter any of them by the lips more than two or three vibrations, except the lowest. We may here note that the power of a resonator to reinforce the different notes of a series of tones, with the prime or fundamental one of which it is not truly in unison, is much greater for the fundamental than for the higher notes; and this gives the reason for the ease with which the fundamental note of a wind instrument may be varied within pretty wide limits, say half a tone sharper or flatter than its proper pitch. Taking, for illustra-

tion, a closed tube 21 inches long, it will be found to give appreciable resonance to a fork of 128 vibrations with quarter wave-length of $26\frac{1}{4}$ inches, but scarcely any to a fork of 384 vibrations (g' the twelfth from c 128) with quarter wave-length of $8\frac{3}{4}$ inches: when the c fork is sounding, the length of the resonance-chamber is to the quarter wave-length as 21 to $26\frac{1}{4}$; but when the g fork is used, the corresponding proportion is practically as $3\frac{1}{2}$ to $8\frac{3}{4}$; for in this case there is a second node at a half wave-length, or $17\frac{1}{2}$ inches from the closed end.

For musical purposes a cylindrical tube blown by the lips is evidently unsuited, by reason of its poor tone, as well as by its giving only the odd intervals. The cone gives the required intervals; but it cannot be used by the lips in its complete form; it would be necessary to cut off a considerable portion to get sufficient width for the action of the lips. Assuming the cone shown on diagram to be cut at the second node of note 4 (counting the node at the apex as the first) and there closed by the lips, that note of the original cone can still be sounded, but no other; the other notes that can be produced may be regarded as the notes 3 and 2 made flatter by their nodes being drawn back, as it were, to the position of node 4, where the cone is cut and the lips are placed; the original notes 2, 3, 4, or c' , g' , c'' , becoming thus the 1st, 2nd, and 3rd notes of a new inharmonic series, with pitches approximately $c\sharp$, eb' , c'' —thus approaching the notes of a cylindrical stopped tube. I have here two other tubes tapering in different degrees—the first two proper tones on the one being c' and $c\sharp''$, and on the other c' and e'' (a major tenth). From these experiments it may be seen that, by using portions of cones of different proportions with their small ends closed, it is possible to get different series of intervals varying between those of an open and those of a closed cylindrical tube—that is, the first interval varying between an octave and a twelfth.

One of the examples just shown (the tube with notes c' and $c\sharp''$) appears to give intervals not very far removed from those required: it may be made use of to illustrate the effect of the combination of a cone with cylindrical tubing, such tubing being of necessity used in practice in connexion with valves or slides to complete the scale. Flattening this cone a fourth, from c' to g , by adding tube, it gives the intervals g , e' , c'' in

place of the g , g' , d'' required, or the ratios 1, $1\frac{2}{3}$, 3 in place of 1, 2, 3, the second interval being actually greater than the first.

These illustrations prove that neither a conic frustum, nor a conic frustum combined with cylindrical tubing, can truly be resonators to notes in the natural harmonic series; but seeing that a bugle or other wind instrument, although it has a considerable diameter at the mouthpiece, may nevertheless be in tune, it appears that its nodal points cannot be in the same positions as those in the cone. On the diagram is represented a bugle of the same pitch as the open tube and cone, with the positions of its nodes and semi-ventral segments as determined by experiment with tuning-forks. Comparing on the diagram the positions of the nodes of any given note in both the bugle and the cone, it will be noticed that there are great differences. The nodes of note 2 show this clearly. Compare lengths from both ends: from mouthpiece to node the length is more nearly equal to that between similar nodes on cylindrical tubing than to that between similar nodes on the cone; but from node to open end it is greater than on the cone, the bugle opening more rapidly.

Thus, then, by altering the proportions of the different semi-ventral segments of which such an instrument may be conceived to be built up, the positions of the nodes may be so arranged that there shall be a node for every note of the harmonic series at the mouthpiece as required; and according as that is more or less perfectly effected will the instrument be more or less perfectly in tune. This bugle is divided into its seven semi-ventral segments for its 4th note, c 512, according to the diagram; and it will be found that by blowing at any one of the nodal points, with any length of the bugle containing an odd number of semi-ventral segments, the note c'' can be produced. The total number of pieces and combinations that can give this note is eighteen.

Having given these few illustrations of the conditions upon which correct intonation, or the relative pitch of the different notes that can be sounded on a brass instrument, depends, I will now endeavour to show the connexion there is between this point and the question of quality of tone, understanding by quality of tone that characteristic of sound which enables

us to recognize a difference between tones of the same pitch. Helmholtz has fully demonstrated that it is only in exceptional cases that we hear a simple musical tone—the vast majority of musical tones being in reality compound tones, in which the fundamental or prime tone has blended with it many upper partial tones of the natural harmonic series,—and that the variety of quality of tone depends mainly upon the number and intensity of these upper partial tones. Blowing the note *c* 256 on three resonators of different forms we get three distinctly different qualities of tone: the resonators now used are a common paraffin-lamp chimney, the conic frustum already shown (having for its first two proper tones *c'* and *c''#*), and the bugle. Analyzing these three tones by tuning-forks or resonators, we find that the lamp-chimney of irregular form gives no upper partials; the tone is pure or simple. The cone has the second and third partials sounding, but not strongly, as it is not strictly in tune for them, or, in other words, there is a difference of phase between the prime tone and the partials. And the bugle has all the partials up to the seventh, gradually diminishing in power, but all tolerably strong up to the fifth inclusive. Slightly altering the form of the cone by adding tubing to the narrow end, and maintaining the original pitch of the prime tone (*c* 256), by cutting a portion off the wide end the pitch of the second tone may be altered until it is *c* 512, an exact octave from the prime; and we find that the quality of tone of the prime or fundamental note is altered, owing to the more perfect resonance which the cone now gives to its second partial. In its original form, with proper tones *c'*—*c''#*, the cone could give but an imperfect resonance to *c''*, the second partial to its prime *c'*.

In the trombone and the euphonion we have two instruments of very different and characteristic qualities of tones—the trombone being brilliant and piercing, and the euphonion mellow. We may take the *B $\flat$* of about 120 vibrations (army pitch) on each of these and endeavour to give a visible proof of the existence of high upper partial tones. For this purpose I use small tubular resonators covered at one end with a tightly strained diaphragm or tympanum of goldbeater's skin, against the centre of which is hung a very small bead, or drop of

sealing-wax, by means of a single thread of cocoon-silk. The two resonators now used are tuned respectively to the fourth and ninth partials of B $\flat$, or b $\flat$ of 480 vibrations and c''' of 1024. When the proper tone of such a resonator is sounded in its neighbourhood, either as a simple tone or as a partial in a compound tone, the agitation of the membrane puts the bead in violent motion, which can easily be seen in the image thrown on the screen by the electric lamp. It will be noticed that when B $\flat$ is sounded, either on the euphonion or on the trombone, both resonators are agitated—but that the excursions of the bead due to the partial tone of 1024 vibrations are much greater with the latter than with the former instrument, although both are played with but moderate force, thus proving that, though partials as high as the ninth exist in the quality of tone produced by both these instruments, yet in the trombone the upper partials have much greater strength than in the euphonion. With a resonator more suitable for private experiment than these, I have distinctly heard the sixteenth partial tone in the B $\flat$ of the trombone. A tapering tube open at both ends, or a common wine-bottle with the bottom knocked out, is very convenient for analyzing tones. Sinking such a tube in water and holding the ear close against the small end, the various partials existing in a given compound tone may be readily discerned, as the length of the tube changes according to the depth it is immersed in the water.

Although one wind instrument may be made to approach another in quality of tone by means of different methods of blowing, and it is therefore not so easy to analyze the tones of these as it is those of keyed instruments with fixed tones, yet I have endeavoured to establish some general data; and these I will lay before you. The instruments the tones of which I have analyzed are the B $\flat$ tenor trombone, the B $\flat$ euphonion, the F French horn, the B $\flat$ cornet, and the bugle. The partial tones named in the Table are those heard when the instruments are gently blown; with loud blowing higher tones can be discerned. The ordinary marks of musical expression, *pp*, *p*, *mf*, *f*, are added in cases where I found it possible to make a comparison.

Instrument.	Note.	No. of vibrations.	Partial tones heard.
Bb Trombone ...	B $\flat$	60	1, 2, 3, 4, 5, 6, &c. to 16. <i>p</i>
	Bb	120	1, 2, 3, 4, 5, 6, &c. to 12. <i>p</i>
	<i>f</i>	180	1, 2, 3, 4, 5, 6, 7. <i>p</i> [than 12 weak.
Bb Euphonion ...	B $\flat$	60	1, 2, 3, 4, 5, 6, &c. to 12; higher <i>p</i>
	Bb	120	1, 2, 3, 4, 5, 6, 7. <i>f mf p</i>
	<i>f</i>	180	1, 2, 3, 4, 5. <i>p</i>
F French horn ...	<i>c</i>	135	1, 2, 3, 4, 5, 6, 7, 8. <i>mf p pp</i>
	<i>f</i>	180	1, 2, 3, 4, 5, 6. <i>mf p</i>
	<i>f</i>	360	1, 2, 3, 4, 5, 6. <i>p p</i>
Bb Cornet.....	b $\flat$	240	1, 2, 3, 4, 5, 6, 7, 8. <i>f f p p</i>
Bugle.....	...	256	1, 2, 3, 4, 5, 6, 7. <i>f mf p pp</i>

While submitting that the different qualities of tone are accounted for by the difference in the number and force of the upper partials in any given compound tone, I must at the same time acknowledge that I can do no more than throw out a few suggestions with respect to the causes that influence the production of such upper partials in this remarkable manner. The partials being in the natural harmonic series, it is evident that if the various proper tones of a vibrating column of air such as is enclosed in a wind instrument are not in exact agreement with this series, the resonance to the partials cannot be at its best. Take for illustration two instruments nominally the same (say two bugles), but with somewhat different qualities of tone. Suppose that a certain compound tone on both should have its first and second partials of equal intensity, but that one instrument has that one of its proper tones that is nearest in pitch to the required second partial a semitone sharper than that partial; the supposed compound tone sounded on that instrument will be deficient in the quality the second partial should give.

As regards instruments of different characters, the chief points influencing the tone are the general form of the instrument (understanding by this the proportions of the column of

air, and not the shape into which the instrument may be bent up for the convenience of the player), the extent of the flanging of the bell, and the form of the mouthpiece. As an illustration of the first of these conditions the trombone may be compared with the euphonion; the tubing of the trombone is cylindrical for about two thirds of its length from the mouthpiece, but the euphonion opens with gradually increasing curvature from the mouthpiece to the rim of the bell. The high upper partials being more powerful on the former than on the latter instrument, it would appear that the cylindrical tubing has the power of maintaining the intensity of the short waves to a greater extent than the tapering tubing has. The bell-flange may be increased in size to a considerable degree without altering the pitch of an instrument; but such increase has a marked effect on the quality of tone, greatly subduing the force of the upper partials. I find by experiment that the pitch is not altered by the extension of the flange curvature beyond a point at which its tangent would make an angle of about 40° with the axis of the instrument, although the quality of tone is decidedly altered by such extension. This may be illustrated by changing the bell-end of a bugle for a bell with much wider flange, more like that of a French horn: comparing the two, it will be noticed that the change in quality of tone is very marked.

The form of the cup of the mouthpiece varies for different instruments, from that of a long deep conical funnel to that of a comparatively shallow well-rounded cup—the first form representing the French-horn mouthpiece, and the second the mouthpiece for instruments of brilliant tone, as the trumpet and trombone; those for cornets, bugles, and saxhorns are of an intermediate character. Although it is manifest that a shallow cupped mouthpiece favours the production of high upper partials, I have not as yet succeeded in arranging any experiments which would illustrate the cause of this. One fact, however, noticed by many observers, appears to me to be suggestive, and worth bearing in mind in connexion with this subject. It is this:—If a vibrating tuning-fork be placed on a sounding-board, the quality of tone it gives varies with the pressure applied: touching the board very lightly with the fork the prime tone is well heard; but on pressing the fork

down to the board the tone appears to jump up an octave; at least the second partial (octave of the prime) is heard with great distinctness. This experiment appears to prove that if an elastic resonant body (in this case the resonant board) is in a state of initial pressure at the point of origin of vibrations, a vibration that would otherwise be simply pendular becomes a vibration compounded of two or more simple pendular vibrations. Applying this consideration to wind instruments, and bearing in mind the initial pressure caused by the escape of air from the lips, it would appear probable that mouth-pieces of different forms so modify this initial pressure as to cause a variety in the number and intensity of the upper partial tones.

XXIX. *On Salt Solutions and Attached Water.*

By FREDERICK GUTHRIE.

[Continued from p. 102.]

VI.

Further Examples of Cryohydrates and Cryogens.

§ 167. *Hydrate of Barium.*—On cooling a saturated solution of this salt, the well-known recognizable crystals are continually deposited until the temperature reaches $-0^{\circ}5$. At this temperature the cryohydrate is formed, the temperature remaining constant until solidification is complete. The barium was estimated by adding carbonate of ammonium and gently igniting.

grams.	BaO CO ₂ .	BaO.	BaO per cent.
22·1204	gave 0·4271	or 0·331707	or 1·4995
19·6436	„ 0·3790	„ 0·29435	„ 1·4984
14·7921	„ 0·2924	„ 0·22709	„ 1·5352

The above analyses are of three separate liquid residues after the separation of two crops of cryohydrate in each case.

The water-worth calculated on the whole three of these results is 565.

As a cryogen the same temperature ($-0^{\circ}5$) was obtained.

§ 168. *Hydrate of Strontium.*—On lowering the temperature of a saturated solution of this hydrate, crystals of the same

separated until the temperature $-0^{\circ}\cdot 1$ was reached ; the cryohydrate then formed.

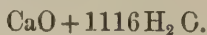
grams.	SrO CO_2 .	SrO .	SrO per cent.
17·2620	gave 0·0944	or 0·5468	or 0·3838
13·5124	„ 0·0774	„ 0·5728	„ 0·4020

The analyses were of different liquid residues after two crops of cryohydrate had been separated from each. The waterworth derived from the mean of these two analyses appears to be 1463. As cryogens, $\text{SrO H}_2\text{O}$ or SrO when mixed with ice did not lower the temperature below 0° . A very slight fall to $-0^{\circ}\cdot 09$ was obtained on slaking SrO with water and allowing it to assume the normal temperature before mixing with ice. Such a fall, however, can scarcely be recognized.

§ 169. *Hydrate of Calcium*.—This body, as is well known, presents the very interesting peculiarity of being more soluble in cold than in hot water. On further cooling the solution saturated at a certain temperature above 0° , one gets an imperfectly saturated solution ; and on still further cooling, ice appears. But if the solution be kept saturated during cooling, which can be well effected by continued stirring with some hydrate precipitated by rise of temperature in another quantity, the cryohydrate appears at $-0^{\circ}\cdot 15$.

grams.	CaO CO_2 .	CaO .	CaO per cent.
22·1094	gave 0·1030	or 0·057630	or 0·26
23·3498	„ 0·1222	„ 0·068432	„ 0·29

The analyses were of different liquid residues after two crops of cryohydrate had separated : the mean of these two results corresponds to the relation



Employed as a cryogen, $-0^{\circ}\cdot 18$ was the lowest temperature reached. The only data I can find of the solubility of lime at different temperatures are those of Dalton ; from whose experiments it appeared that lime-water saturated at

100° C.	contains	0·1050	per cent. of $\text{CaO H}_2\text{O}$
54·4	„	0·1371	„ „
15·5	„	0·1712	„ „

From my results it appears that, the mean CaO being 0.275 per cent. (the mean of two analyses of the cryohydrate at $-0^{\circ}\cdot 15$ gave 0.3634 per cent. of $\text{CaO H}_2\text{O}$), lime is $3\frac{1}{2}$ times more soluble in water at $-0^{\circ}\cdot 15$ C. than at 100 C.

With regard to these water-worths,

	W.W.
Hydrate of barium	565
„ strontium	1463
„ calcium	1116

it is not only noteworthy, but imperatively demands notice, that here calcium lies between barium and strontium. They who are engaged with the spectra of these metals will scarcely need a further hint.

The melted cryohydrates of $\text{SrO H}_2\text{O}$ and $\text{CaO H}_2\text{O}$, which had been solidified in an ice and NaCl freezing-mixture, did not exhibit the characteristic opacity of cryohydrates. They became milky in a carbonic acid and ether cryogen, but did not seem even then to assume the characteristic opacity. A trace of this true opacity appeared with $\text{BaO H}_2\text{O}$.

§ 170. *Hydrate of Potassium*.—A concentrated solution, namely a solution resulting from the deliquescence of the solid hydrate in moist air free from carbonic acid, did not solidify on being subjected to a cryogen of CO_2 and ether: it, however, became syrupy. A dilute solution (indefinite) solidified wholly within the range of an ice-and- NaCl cryogen. The solid was transparent and resembled ice; it sank in water at 0° C.

As a cryogen, caustic potash gave a temperature of $-19^{\circ}\cdot 2$ C. But, as will appear subsequently (and this is an important point), a salt which evolves heat on mixing with water makes a more powerful cryogen with ice if previously cooled; not so those which do not.

§ 171. *Permanganate of Potassium*.—On cooling a saturated solution of this salt, crystals of the permanganate separated out down to 0° C. The cryohydrate was formed at $-0^{\circ}\cdot 57$; and the temperature then ceased to sink. The estimation of the water was by evaporation at 100° . The samples are from different preparations. In each case several crops of the solid cryohydrate had been removed.

grams:	Anhydrous salt.	Per cent.
20.4624	0.5874	2.871
19.6134	0.5910	3.013
19.7115	0.5249	2.663
19.7476	0.5318	2.693
12.6320	0.3718	2.943

The mean of these rather discordant results shows a water-worth of 608.3 (K_2MnO_8).

As a cryogen, permanganate of potash gives a temperature of $-0^{\circ}.52$.

§ 172. *Acetate of Lead*.—The cryohydrate of acetate of lead forms at $-1^{\circ}.4$ C. After the separation of several crops, in each case the residual liquids, after weighing, were repeatedly evaporated with an excess of nitric acid and gently heated. It is found that the acetate is thereby completely converted into the nitrate.

grams.	Nitrate.	Per cent. of acetate.
14.8195 gave	2.7906	= 18.4
6.9029 „	1.2401	= 17.5
7.4904 „	1.3700	= 18.0

The water-worth, calculated on the mean of these three results, is 82.3. The temperature of the acetate-of-lead cryogen is $-1^{\circ}.7$.

§ 173. *Sulphate of Zinc and Potassium*.—The cryohydrate forms at $-1^{\circ}.25$. The analyses are, as before, of different residual liquids. The liquid cryohydrate was evaporated to dryness at 100° and heated to incipient fusion.

grams.	$ZnSO_4 + K_2SO_4$.	Per cent.
9.1020 yielded	0.7274	or 7.992
9.0934 „	0.7739	„ 8.510

The mean of these results gives the water-worth 167.4. As a cryogen, the same double salt gives $-1^{\circ}.01$. The temperature of solidification of this cryohydrate and the percentage of salt it contains are approximately those of K_2SO_4 , its least-soluble constituent (see §§ 22, 71).

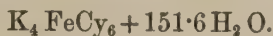
	Temperature of cryohydrate.	Per cent. of salt.
K_2SO_4	$-1^{\circ}.5$	7.8
$ZnSO_4$	-7°	30.84
$K_2SO_4 + ZnSO_4$	$-1^{\circ}.25$	8.25

Comparing this fact with those developed in §§ 109-120, where mixtures of salts were employed, we find that while with such mixtures the more powerful cryogen governs the temperature, here it is the less powerful cryogen which does so.

§ 174. *Ferrocyanide of Potassium*.—The cryohydrate of this salt forms at $-1^{\circ}7$. Two analyses of the same residual liquid were made by evaporating at 100° , and subsequent stirring with free exposure to the air at the same temperature.

grams.	K_4FeCy_6 .	Per cent.
6.6510	gave 0.7987	or 12
6.5080	„ 0.7665	„ 11.8

The mean indicates the formula



The temperature of the cryogen is $-1^{\circ}61$. If this body had been the first to be experimented on in the direction which has led to the discovery of the cryohydrates, it is possible that the whole class might have escaped notice, because, when the cryohydrate is allowed to melt, a considerable quantity of yellow salt (terhydrate or subcryohydrate) falls down unless the liquid is kept well agitated. Though not peculiar to this salt, it is perhaps more marked with it than with any other. To be viewed almost as a corollary to the above fact is the following one concerning the same salt. When a solution of the strength of the cryohydrate is cooled, there may be a simultaneous formation of ice and some hydrated or anhydrous ferrocyanide: the one floats; the other sinks. As before pointed out in other cases, this independent separation of the constituents of the cryohydrate is entirely prevented by placing in the solution a fragment of previously formed cryohydrate.

§ 175. *Ferricyanide of Potassium*.—At a temperature of $-3^{\circ}9$ a saturated solution of this salt began to give up its cryohydrate, having previously given up a less hydrated salt. Though several determinations of the amount of salt in the residual liquid were made both by evaporation over a water-bath and drying *in vacuo* over sulphuric acid, the results differed from one another by several per cent. The lowest was 19.8 per cent., the highest 24 per cent. The temperature of the cryogen is $-3^{\circ}9$ C. The ambiguity in the amount of

water in the cryohydrate finds its counterpart in the similar ambiguity in the water of crystallization of the ordinary salt.

§ 176. *Nitrate of Urea*.—The cryohydrate first appears at -4° , on cooling a saturated solution. The residual liquids from two preparations, after about the same quantity of cryohydrate had separated, were very gently evaporated on a water-bath only just to complete dryness. If the substance be further heated, minute iridescent crystals begin to appear at that part of the residue where the basin is in contact with the bath. As soon as these began to appear the further heating was stopped.

grams.	Nitrate.	Per cent.
6.6889	gave 0.5693	or 8.64
6.7616	„ 0.5844	„ 8.51

The water-worth is accordingly 72.83. As a cryogen the temperature of $-4^{\circ}.5$ is obtained.

§ 177. *Oxalate of Potassium*.—The temperature at which the cryohydrate formed was found to be $-6^{\circ}.3$. On evaporating 3.2862 grams in a platinum capsule, igniting, and quickly cooling on a metal slab, 0.5790 of the carbonate was obtained (=17.62 per cent.).

In another analysis, 3.1500 grams, on evaporation to dryness on a water-bath, gave 0.6684 oxalate (21.22 per cent.). This gave on ignition 0.5531 of carbonate (17.56 per cent.), which by treatment with hydrochloric acid gave 0.5958 of chloride of potassium (18.88 per cent.). The percentage of carbonate agrees closely with that of the first analysis. The percentage of chloride differs only by 0.07 from that required on the conversion of 17.56 of carbonate. Hence it would seem that with due care oxalate of potassium may safely be estimated as carbonate, notwithstanding the hygroscopic character of the latter salt. It also appears (contrary to statements sometimes made) that oxalate of potassium does not retain any of its water of crystallization when its solution is evaporated to dryness at 100° C.; for the 17.56 per cent. of carbonate obtained is equivalent to 21.12 per cent. of oxalate, which only differs by 0.1 per cent. from 21.22, which was found. The water-worth (deduced from the chloride of potassium) is 17.3.

The temperature of the cryogen is $-6^{\circ}.2$.

§ 178. *Fluoride of Sodium*.—This salt, like several other salts of sodium, is troublesome when attacked from the side of saturated solutions, because there appears to be a subcryohydrate. This salt also exhibits the very rare property of being almost equally soluble at all temperatures between 100° and $-3^{\circ}9$. On cooling a hot saturated solution to -2° , nothing separates. Between -2° and -4° an ice-like body is formed. The true cryohydrate appears to be formed at $-5^{\circ}63$; for this temperature is preserved till the whole is solid and opaque. Fluoride of sodium, as a cryogen, gives $-3^{\circ}2$. The cryohydrate has not been further examined.

§ 179. *Cyanide of Mercury*.—A concentrated solution gave up the anhydrous salt until $-0^{\circ}45$ was reached; then the cryohydrate was formed. The amount of salt was determined by evaporation over sulphuric acid *in vacuo*.

grams.	Cyanide.
3.8835	gave 0.2892 or 7.45 per cent.
5.0238	„ 0.3738 or 7.44 „

This percentage exhibits the water-worth of 174. The same salt as a cryogen reaches the temperature $-0^{\circ}6$.

§ 180. *Acetate of Zinc*.—A boiling saturated solution was allowed to cool to the atmospheric temperature ($+15^{\circ}$). The residual liquid was drained from the separated crystals and introduced, together with a few crystals, into a stoppered bottle. After keeping in ice for nine hours with frequent agitation, all sign of further crystallization ceased. The zinc was estimated by precipitation with carbonate of sodium. It was thus found that the strength at 0° was 23 per cent. This solution, when artificially cooled, yields fern-like crystals at $-5^{\circ}9$; these gradually became opaque, the opacity forming in a frond-like manner; the whole became dry at the above temperature. An analysis of the residual liquid, after two crops of cryohydrate, showed that the cryohydrate had sensibly the same composition as the solution saturated at 0° C.; for

grms.	Oxide.
5.9980	gave 0.6103 or 23 per cent. anhydrous acetate.

§ 181. *Hyposulphite of Soda*.—The following are the temperatures at which solidification begins in solutions of varying strengths of this salt:—

TABLE XXXIX.

$N_2S_2O_3$, by weight.	Temperature, Centigrade.	Body found.
per cent.		
1	- 0.1	Ice.
2	- 0.4	"
3	- 0.65	"
5	- 1.2	"
6	- 1.5	Appearance of ice, but sinks in water at 0°. Perhaps due to interstitial solution. More probably a subcryo- hydrate.
10	- 2.5	
15	- 3.9	
20	- 5.45	
30	- 9.5 to -11.0	
30	-11	Cryohydrate.
33.5.5	0.0	Ordinary hydrate.
41	+20	

A 30-per-cent. solution does not always give up a solid at $-9^{\circ}5$. Sometimes the temperature sinks to $-12^{\circ}4$; then the true cryohydrate is formed, and the temperature rises to -11° and remains constant till all is solid.

The solubilities at 0° and 20° are those given by Kremers. These and the determination for -11° , when plotted in the usual way, are found to lie on the same straight line. H. Schiff found at $19^{\circ}5$ a saturated solution to contain 63.5 per cent. five-hydrated, or 45.8 per per cent. anhydrous salt. As a cryogen, the temperature -10° was reached.

§ 182. *Citric Acid*.—This body presented many difficulties; but as these difficulties occur again with most organic acids of high molecular weight, a special study was made of it. It is peculiarly liable in aqueous solution to supersaturation of the most persistent kind, especially when the solution is at a low temperature. At temperatures and under conditions which are capable of evolving the cryohydrate, the solution assumes sometimes an almost colloidal form, and shows no signs of eliminating solids unless other means besides mere lowering of temperature are employed.

From solutions ranging from 10 to 40 per cent. of anhydrous acid, ice is liberated; and this continues to 42.26 per cent., from which solution a cryohydrate separates at $-9^{\circ}2$. The following is a somewhat detailed account of the behaviour of solutions containing a greater percentage of acid than 40.

Two grams of a solution gave 0.8525 of citric acid, or 42.28 per cent. This gives a solid at $-9^{\circ}2$, which at first floats on

the residual liquid. The solid consists of massive white agglomerated crystals. The crystals are hexagonal, but present rhomboidal elements, causing the edge of each crystal to be deeply and regularly serrate. When they melt, the rhomboidal crystals are themselves resolved into long slender prisms. A large quantity of such a solution retained its composition when nine tenths of it had been removed by solidification, nevertheless, if such a solution be kept perfectly still for many hours at -9° , a few ice spicula may be formed.

Other solutions, containing respectively 45, 45.9, 50, 50.7, and 51.5 per cent. of the anhydrous acid, were examined. It is only this latter which yields, on cooling, distinct quantities of the original salt: this it does at -6° , but only if a particle of the original salt be introduced and by diligent stirring. When undisturbed, this 51.5 solution may be cooled to $-19^{\circ}.5$ without any solidification. So prone is this acid to exhibit supersaturation, that solutions both weaker and stronger than the 42.62 may be enriched on partial solidification. Thus a 50-per-cent. solution, though already stronger than the cryohydrate, may become still stronger by the separation of ice at -17° . There is therefore a large region of double supersaturation; the ice-curve crosses the acid or suberyohydrate-curve, both continuing their courses for an exceptionally long distance.

For the solubility at 0° C., a solution saturated above 0° C. was kept at 0° surrounded by ice and placed in an ice-safe for three days.

Solution.	Anhydrous acid.	Per cent.	Mean.
2.0962 gave	1.0755	or 51.30	} = 51.285.
2.1288 „	1.0914	„ 51.27	

Crystallized citric acid when added to water has a considerable cooling effect. Thus

110.9 grams of crystallized acid at $20^{\circ}.5$ C., added to
 89 „ water at . . . $16^{\circ}.5$
 lowered the temperature to . . . $2^{\circ}.5$;

while

51.5 grams of anhydrous acid cooled to 0° C. and added to
 48.5 „ water cooled to . . . 0°
 gave a temperature of . . . -6° .

The chief results may be summarized in the following Table:—

TABLE XL.
Citric acid (anhydrous).

Anhydrous acid, per cent.	Temperature at which solidifi- cation begins.	Body formed.
10	— 1.1	Ice.
20	— 2.8	"
30	— 5	"
40	— 8.5	"
42.62	— 9.2	Cryohydrate.
45	— 11.3	At these temperatures ordinary hydrate, sub- cryohydrate, or even ice may be formed.
45.93	— 11.7	
47.06	— 12.2	
50.7	— 13.7	
51.5	— 15	

As a cryogen, the lowest temperature attainable is $-9^{\circ}3$; and this confirms the composition of the cryohydrate which had been deduced synthetically. Neither cooling the acid to 0° C. nor cooling the two separately to -9° C. had any effect upon the temperature; but, of course, the more nearly the initial temperature is to the final one the less is the quantity of liquid formed.

Miscellaneous Notes.

§ 183. The following notes of salts which have not yet been fully examined may be useful.

Cyanide of Potassium, as a cryogen, gives a temperature of $-21^{\circ}1$. The cryohydrate forms at -33° , with a carbonic-acid and-ether cryogen. Compare § 170.

Oxalate of Sodium forms a cryohydrate at $-1^{\circ}7$ C.

Employed as cryogens, the following temperatures were obtained from the corresponding salts:—

Chloride of cadmium . . .	— 8.3 C.
„ nickel . . .	— 10.35
Citrate of sodium . . .	— 11.3
Acetate of calcium . . .	— 11.8
Chloride of cobalt . . .	— 15.35
„ manganese . . .	— 28.0

Those of these bodies which evolve heat on mixture with water would, when cooled, depress the temperature more. Thus the chloride of manganese scarcely showed signs of a cryohydrate at -40° C.

Formate of Sodium, as a cryogen, gives $-14^{\circ}3$. A concentrated solution becomes semisolid at -14° , but does not become opaque or completely solid in a salt-ice cryogen (-22°).

Tannic Acid, as a cryogen, gives $-1^{\circ}5$.

Sulphurous Acid gives a cryohydrate at $-1^{\circ}5$.

Boracic Acid, as a cryogen, gives $-0^{\circ}8$. The cryohydrate forms at $-0^{\circ}7$.

Arsenious Acid.—The cryogen stands at $-0^{\circ}3$; the cryohydrate formed at $-0^{\circ}5$. Two samples of the melted and liquid cryohydrate were sealed hermetically. After two or three days it was found that a considerable quantity of a fine white powder had exhibited itself.

On the Separation of Water from Crystalline Solids, in Currents of Dry Air.

§ 184. The high water-worth of many of the cryohydrates (§ 88), and the want of evidence of simple arithmetical relationship between the atomic numbers of the water and salt of almost all these bodies, invited me to reexamine a few of the most definite and stable crystalline salts containing water. And this invitation was the more pressing because, in the matter of the determination of water of crystallization, analysts have for the most part allowed themselves a far greater latitude in respect to agreement between the experiment made and the conclusion drawn than they have been willing to admit in regard to the other constituents of the salt. Prominent in respect to agreement between experiment and the derived constitution are the investigations of Graham, especially on the water of crystallization of single and double sulphates. Such accord is so rare, that in a very great many instances the experiments actually point to a different water-worth than that adopted by the experimenter.

That heat is sometimes liberated and sometimes absorbed when a salt is brought into contact with water, not only according to the nature of the anhydrous constituents, but also

to the degree of hydration, has long since shown that there is some essential difference in the tension of the union which is established between the water on the one hand, and the more or less hydrated anhydride on the other. But the statements as to the conditions under which a salt becomes anhydrous, or exists in combination with a definite relative number of molecules of water, are neither definite nor satisfactory. The statement that a salt gives up n molecules of water when heated to the temperature E is inexact, (1) unless the hygrometric state of the air is given, (2) unless it is known whether free circulation takes place, and (3) unless the pressure on the salt is known. The statement that a salt gives up m molecules of water *in vacuo* (over a desiccator) is also ambiguous, in so far as it ignores the temperature.

The salt which I first examined in this respect was chloride of barium, $\text{BaCl}_2 + 2\text{H}_2\text{O}$ ($\text{BaCl} + 2\text{HO}$), it being a salt easily got quite pure and of a stable nature. The "pure" salt of commerce was recrystallized, boiled with carbonate of barium, filtered and precipitated, and washed with alcohol. It was then twice recrystallized. It was then finely powdered, and a part A was dried for forty-eight hours in a good vacuum at a temperature of about 17°C .; a part B was dried between repeatedly renewed bibulous paper in a screw-press for the same time. Two analyses of each were made, the elements being estimated in the usual way.

Estimation of Barium.

	Weight of substance.	Sulphate.	Barium.	Per cent. of barium.
A (1)	2.7768	2.6912	1.57061	56.563
A (2)	1.3997	1.3406	0.78825	56.560
B (1)	1.3942	1.3445	0.79054	56.703
B (2)	0.8847	0.8480	0.49857	56.360

Estimation of Chlorine.

	Weight of substance.	Chloride of silver.	Chlorine.	Per cent. of chlorine.
A (1)	0.6579	0.7640	0.18900	28.72
A (2)	0.8559	0.9970	0.24665	28.70
B (1)	0.8849	1.0344	0.25590	28.92
B (2)	1.3965	1.6344	0.40433	28.91

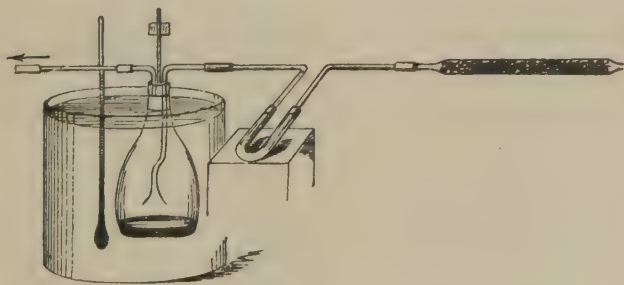
(Ba = 137, Ag = 108, S = 32, O = 16, Cl = 35.5).

Hence

	Calculated.	Dried <i>in vacuo</i> . Mean.	Dried between paper. Mean.
Ba . .	56·139	56·561	56·531
Cl ₂ . .	29·098	28·912	28·710
2 H ₂ O . .	14·754	14·527	14·795
	<u>100·000</u>	<u>100·000</u>	<u>100·000</u>

From these analyses, and from the direction of their divergence from the theoretical composition of the salt, there can be no doubt about the composition of the salt ; nor is there any doubt that the water is present in simple molecular ratio. Accordingly the hydrated chloride of barium is admirably adapted for examination as to the conditions under which it gives up water. The only statement I can find in this respect is that the hydrated salt gives up the whole of its water at 100° C.

§ 185. A two-ounce flask with the lip cut off was provided with a glass cap for use alone in the balance-case: the figure explains the rest. A given volume of air (measured by the



quantity of water leaving the gasometer) is drawn in a given time over a thin layer of the hydrated salt, while the latter is heated to a given temperature. The air passes first through a long tube containing fragments of hydrate of potassium, and then through a tube containing glass and sulphuric acid.

As the flask had to be left for half an hour in the balance-case every time before weighing, the above experiments occupied a few weeks. At the end of this time the flask was found to have lost 0·0017 gram.

TABLE XLI.

Substance = 4.1605.

Volume of air drawn through flask at uniform rate of 3300 cubic centims. in 60 minutes.	Temperature.	Loss.	Loss by 3300 cubic centims.
cub. cent.	°		
26400	17	0.0008	0.0001
3300	25	0.0000	0.0000
"	40	0.0063	0.0063
"	"	0.0073	0.0073
"	"	0.0078	0.0078
"	"	0.0075	0.0075
"	"	0.0075	0.0075
"	"	0.0071	0.0071
"	"	0.0052	0.0052 (in 45')
"	"	0.0078	0.0078
"	"	0.0066	0.0066
"	"	0.0062	0.0062
"	"	0.0044	0.0044 (in 30')
"	"	0.0060	0.0060
19800	"	0.0412	0.0069
"	"	0.0420	0.0070
"	"	0.0346	0.0058
"	"	0.0407	0.0068
"	"	0.0340	0.0057
9900	"	0.0105	0.0035
"	"	0.0044	0.0015
"	"	0.0022	0.0007
"	"	0.0020	0.0007
19800	"	0.0029	0.0005
"	"	0.0059	0.0009
"	"	0.0000	0.0000
"	60	0.0063	0.0011
9900	70	0.0099	0.0033
19800	70	0.0256	0.0043
9900	70	0.0090	0.0030
9900	50	0.0000	0.0000
9900	50	0.0000	0.0000
9900	60	0.0038	0.0013
19800	70	0.0210	0.0035
9900	55	0.0000	0.0000
9900	58	0.0000	0.0000
9900	59	0.0000	0.0000
9900	60	0.0038	0.0013
19800	70	0.0187	0.0031
26400	70	0.0259	0.0032
39600	70	0.0411	0.0034
9900	80	0.0239	0.0080
9900	90	0.0483	0.0161
9900	90	0.0358	0.0119
9900	80	0.0151	0.0050
9900	80	0.0182	0.0061
9900	60	0.0010	0.0003
9900	90	0.0021	0.0007
6600	100	0.0000	0.0000

Examining the final result as a direct determination of the whole of the water, I found that the 4.1605 grams had lost 0.6087 gram, or 14.63 per cent., instead of the theoretical amount 14.75.

The actual weight of water which a given weight of the salt lost at a given temperature in a given time has little interest, because it is conditioned by the attitude of the salt to the air-current in the flask, and it is also governed by the rate. But points of very great interest are nevertheless presented when the above numbers are compared. The first loss, at 17° C., may probably be attributable to the more complete drying of the salt, since no further loss was experienced at 25°. Starting at 40°, a considerable loss was experienced, which continued with very considerable regularity until the residue approached in composition to the one-atom hydrate $\text{BaCl}_2 + \text{H}_2\text{O}$; the loss then suddenly diminished and abruptly stopped. The total loss experienced by the 4.1605 grams of salt when this point was reached is 0.3009—that is, 7.21 per cent. As the percentage of water in $\text{BaCl}_2 + \text{H}_2\text{O}$ is 7.37, there can be no question that there is a difference in the strength of union of the two water molecules to the salt, or, more exactly, that it requires different physical conditions to separate $\alpha \text{H}_2\text{O}$ from BaCl_2 than are sufficient to separate $\beta \text{H}_2\text{O}$ from $\alpha \text{H}_2\text{O}$, BaCl_2 .

At what minimum temperature the β molecule begins to be separated is missed in this Table: it lies somewhere between 25° and 40°. But it appears that when the temperature is such that one molecule begins to be stirred, the whole of that molecule is removed if the current of dry air be continued. In the case of the chloride of barium, there is a range of temperature below 60° and reaching down to the above-mentioned minimum, in which the α molecule is fixed while the β molecule is removable.

The minimum temperature required to disconnect the α molecule is well marked. The salt having ceased to lose weight at 40° C., lost weight distinctly at 60°, and still more rapidly at 70°. On reducing the temperature to 50° no loss could be detected; at 60° the same as before, and at 70° the same as before. At 55° there was no loss, nor at 58°, nor at 59°; but at 60° the original loss was reestablished. And until the salt is becoming anhydrous, for each temperature there is a pretty constant loss.

The anhydrous BaCl_2 thus obtained, when mixed with water, may raise the temperature from 19° to 38° . The solution is perfectly limpid and neutral.

§ 186. In order to make a more systematic attack on the β molecule, a fresh quantity was taken of the salt which had been dried *in vacuo* over sulphuric acid, and had then stood in air over sulphuric acid for three weeks.

TABLE XLII.

Substance = 5.6462.

Volume of air drawn through at uniform rate of 3300 cubic centims. in 15'.	Temperature.	Loss.	Loss by 3300 cubic centims.
9900	26 ^o	0.0005	.0002
"	29	0.0012	.0004
"	32	0.0025	.0008
"	34	0.0053	.0018
"	36	0.0068	.0023
"	38	0.0089	.0030
"	40	0.0129	.0043
"	50	0.0236	.0079
16500	58	0.1450	.0290
9900	53	0.0446	.0149
"	50	0.0222	.0074
"	45	0.0209	.0070 (in 30')
19800	55.5	0.0821	.0137
"	"	0.0192	.0032
9900	"	0.0022	.0007
6600	"	0.0014	.0007
19800	56	0.0074	.0012
9900	57	0.0029	.0010
"	57	0.0022	.0007
19800	57	0.0000	.0000

It seems that the almost inappreciable loss at 26° is really continuous with the greater losses at higher temperatures. The loss at 25° having been shown in Table XLI. to be inappreciable, we may consider the loss to begin between 25° and 26° . It is observed that the rate in Table XLII. is four times as great as in Table XLI.; and a consequence of this is that, for given volumes at the same temperature (40°), the losses are absolutely and relatively to the quantity less in Table XLII. than in Table XLI., but not four times as small. Hence, as we might anticipate, at a given temperature and for a given volume more water is withdrawn by a slow current than by a

quick one ; while in a given time more water is withdrawn by a quick current than by a slow one. With regard to the first of these facts, it need only be remembered that the slow current becomes more saturated than the quick one. Although the cessation of loss is for both atoms sufficiently well marked and abrupt, the final balance of water is retained in both cases with considerable tenacity.

In the second series of experiments the flask preserved its weight exactly. The total loss on the 5·6462 grams was 0·4119 gram, showing a percentage loss of 7·277.

The whole analysis now stands as follows, allowing for the loss of the glass in the first series, for the salt dried over sulphuric acid :—

	Calculated.
Ba . . . 56·56	56·14
Cl ₂ . . . 28·91	29·10
α H ₂ O . . . 7·44	} 14·76
β H ₂ O . . . 7·23 (7·28 and 7·19)	
100·14	100·00

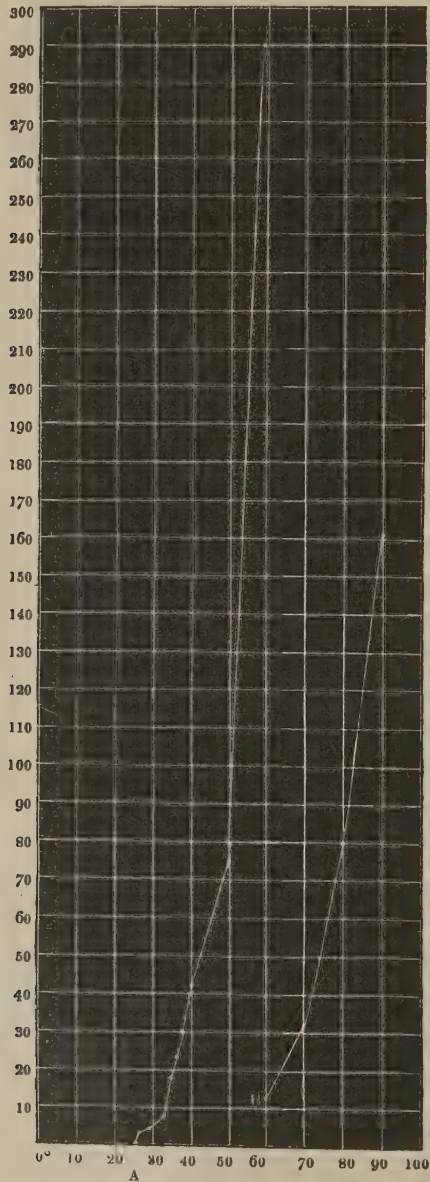
On mixing the body BaCl₂ + H₂ O with water a rise from 21° to 27° (or 6°) was obtained. The anhydrous salt with water gave from 19° to 38° (or 19°).

§ 187. Briefly to recapitulate concerning BaCl₂ + 2 H₂ O. At the ordinary barometric pressure, and in a current of air dried and freed from carbonic acid, one water molecule is removed at all temperatures above 25° C., the other at all temperatures above 60° C. In the figure (p. 112) A shows the rates of loss of the β molecule in tenths of milligrams, the ordinates being proportional to such losses. The abscissæ are the temperatures. B shows the losses in like manner of the α molecule.

Chromatic Value of other Media than Water.

§ 188. There are few media besides water which dissolve metallic salts. Amongst the few glycerine stands preeminent ; and this liquid is indeed comparable with water itself in its solvent power. On account of this very solvent power, there appears to be at present no evidence of the replacement of water by glycerine in solid hydrated salts, similar to the replacement in siliceous jellies. Some glycerates (using the term homologically with hydrates) are well-defined bodies enough ; and the

properties of some new ones will be described subsequently. Here I shall confine myself to the description of the effect upon



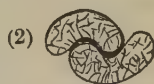
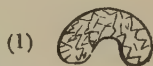
the colours of a few salt solutions, according as the solvent is water or glycerine. Being partially what is called "colour-blind," I have, of course, availed myself of the services of my friends in describing the appearances presented.

§ 189. Many are entertaining the idea of the relationship between the vibrating periods of the light-wave and the mass of the molecule, simple or compound, of the medium. The expression "loading" a molecule, by associating it with another more or less massive molecule, may perhaps be the most convenient term to apply to the cause of the increased period of oscillation which such association entails; but, of course, any systematic obstruction to vibration, any drag, would have the same effect as the drag of inertia.

§ 190. In some experiments relating to the "wandering of the ions" in jellies during electrolysis, which I had the honour of bringing before the Physical Society on the 16th of March, 1878, I described the spreading of the acid and alkaline ions through the unmelted jelly. These results I do not publish, because a friend has had the great kindness to point out to me that many of the results which were then exhibited had been obtained several years previously by Dr. W. M. Ord. The experiments and speculations of Dr. Ord are contained in a very remarkable and suggestive series of papers contributed chiefly to the St. Thomas's Hospital Reports*. Amongst the jellies which I then prepared but did not exhibit, was a stiff gelatine jelly saturated with sulphate of copper. This jelly was of a bright emerald-green by transmitted light. On exposure to the air of a portion which had not been subjected to electrolysis, the water gradually evaporated and the salt began to crystallize out. The form of the crystalline masses was curiously modified by the jelly. Rounded masses were formed, reminding one of my friends of the coccoliths of the deep-sea dredgings—another, of the mineral or uric concretions

* "Some Experiments relating to Forms assumed by Uric Acid" (St. Thomas's Hospital Reports, 1870); "An account of some Experiments relating to the Influence exercised by Colloids upon the Forms of Inorganic Matter" (St. Thomas's Hospital Reports, 1871); "Studies in the Natural History of the Urates" (Rep. Microscopical Society, Jan 6, 1875); "On some Points in the Natural History of Uric Acid and Urates" (St. Thomas's Hospital Reports, 1875); "Urinary Crystals and Calculi," &c. (Medico-Chirurgical Transactions, vol. lviii. March 9, 1875).

which occur in mucous media—and yet another, of “chlorite.” Whether there be, as is most likely, a common cause, a colloid medium, in all the three cases, I must not here discuss. The ultimate crystalline element is too minute for determination; but the elements of secondary form invariably resemble (1). These elements are frequently linked two by two in one plane (2), or at right angles to one another (3). The convex sides are generally very deeply furrowed, so as to give the impression of their being four secondary elements. These concretions can be picked out of the jelly in which they form, like almonds out of a cake. So clean is their separation, and so feeble their blackening when heated with oil of vitriol, that they must be regarded as homogeneous bodies free from gelatine; and their composition is therefore



of no common interest. Ten of these concretions, which are remarkably uniform in size, weighed 0.5024 gram; the loss on heating to 200° C. in an air-current was 0.1432 gram, showing 28.504 per cent. of water. This points to the formula $\text{CuSO}_4 + 3.5 \text{H}_2\text{O}$; and, as I hope to show in my next communication, the subdivision of the water molecule in hydrated sulphate of copper, or rather the multiplication of the whole formula of that salt, does not admit of doubt. Here again we have evidence of the continuity of composition according to physical circumstances (compare § 142). But what a complete chain of difference of diffusive potential is here indicated, stretching from the first nucleus throughout the jelly! and how it suggests the diffusion and accretion of the matter of a crystalline mineral through a colloid and, perhaps, mechanically rigid mineral matrix!

To return to the green colour of the copper jelly. Gelatine is so complex a body, that although the formation of the blue crystals of the sulphate shows that there has been no general chemical change, yet there is no evidence of its entire absence. Glycerine was therefore next employed as a medium for the solution of various coloured salts.

§ 191. Anhydrous sulphate of copper dissolves so abundantly in glycerine that the solution may be almost solid when

cold. There is no sign of crystallization; but the solution at all strengths is a bright emerald-green.

§ 192. Crystals of permanganate of potassium, when heated with glycerine, oxidize it with the escape of gas; but if cold glycerine is added to a cold saturated aqueous solution of the permanganate, a liquid is obtained, without evidence of chemical change, which has been pronounced to be brownish yellow, amber, or, perhaps more accurately, "raw-sienna." In view of the possible chemical change which may be incipient here, it is perhaps better to put this result on one side.

§ 193. Chloride of cobalt, which in water gives the well-known pink hues according to its strength, gives with glycerine a beautiful carmine; this, when heated, is greatly enriched in its blue. When cooled in a carbonic acid cryogen, it acquires a yellowish tint.

§ 194. Chromium potash alum, which in water gives the pale indigo of dilute ink, gives with glycerine an emerald-green.

Whatever be the degree of intimacy of association between the glycerine and the salt, it appears, then, that this association does in all cases retard the light-wave period, or increases its length. The bluing of the cobalt-glycerine solution by heat, and its yellowing by cold also, are entirely in accord with the before-mentioned conception. It may be noticed also that the glycerine solution of a coloured salt is, as a rule, of a much richer colour than the aqueous solution of the same strength by weight or volume.

I cannot but think that these results lend considerable support to the idea mentioned in § 189, which idea has been so far fruitful in Abney's hands that he has been enabled, by associating a metallic salt with a heavy molecule, to fit the vibrating period of a photographically sensitive film to the light which it is desired to record.

I have to express my indebtedness to Mr. A. K. Huntington for the patience, zeal, and skill which he has shown in helping me in the work of the first half of this part (No. VI.) of my research.

XXX *On the Transmission of Vocal and other Sounds by Wires.* By W. J. MILLAR, C.E., Sec. Inst. Engineers and Shipbuilders in Scotland.

1. *Object of Paper.*—The object of the present paper is the description of a series of experiments made by the author upon the transmission of vocal and other sounds by wires, and the results obtained from those experiments.

2. *Transmission of Sound in general.*—The transmission of sound by various media is familiarly illustrated from day to day; and the readiness with which these media are affected has been made the subject of many experiments.

One familiar illustration of the transmission of sound from air to solids and thence back to the air is that which occurs in the vertical and horizontal partitions between rooms, such as partition walls and floor and ceiling spaces—the sounds originating in one room being thus transmitted to the adjoining room without having recourse directly to air communication.

From a consideration of the latter, as also from other phenomena, the author has for some time been convinced that vocal sounds might be transmitted by solid bodies, such as wires, and that to considerable distances.

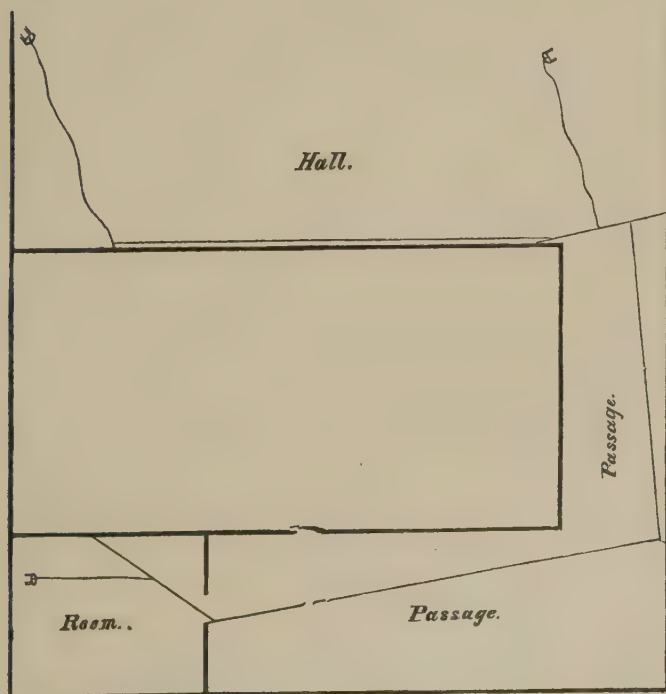
After several unsuccessful attempts, the author during the month of January last, having occasion to use some fine copper wire, carried a portion of it out from the house to a distance of about 20 yards, and attached a couple of pasteboard disks with low rims to the ends of the wire: the transmission of vocal sounds was then found to be easily effected, conversation being readily carried on through this length of wire.

Since that time the author has made many experiments with various combinations and under various circumstances. The principle upon which they all more or less appear to depend, so far as the rendering audible of the sounds, is that of the tuning-fork and sounding-box, in which the sound from the vibratory movements of a metal body is considerably intensified when the body is placed upon a sonorous substance affecting the air in its vicinity.

3. *Notes of some of the more important Experiments.*

(1) No. 23 copper wire was stretched between windows outside of house, and attachments at right angles made to rooms through the windows. Speaking in one room was then heard in the other; the distance was about 20 yards. Pianoforte music was easily transmitted by placing an ear-piece inside the instrument and carrying the other end of the wire outside the house.

(2) No. 40 copper wire fitted up in a building, passing from room to room as per diagram below. Six attachments and angles.



Distance about 50 yards. Conversation, singing, whistling, breathing, and the sound of a light C tuning-fork ($2\frac{1}{4}$ inches in fork) readily transmitted.

Various similar arrangements were also made in house from room to room, and finally carried to a distance outside, when all the above effects, as also the transmission of whispering,

were clearly demonstrated, the persons at either end being quite out of hearing in the ordinary manner.

The communication was not limited to the persons at either end of the wire ; additional connexions were occasionally made, when three or more individuals could communicate with each other.

(3) Carried about 7 yards of No. 23 copper wire from one room through an adjoining one to a room beyond, the wire in its course passing *below two doors* shut above it, and for the most part in *contact with the carpet*, but fastened at the ends so as to produce some tension. Made two connexions of No. 40 copper wire at angles with the main wire ; conversation was then readily carried on, and all the phenomena already described produced. Subsequent experiments with No. 16 copper wire arranged as above were found to yield better results.

A somewhat similar and equally successful experiment was made by carrying the same size of wire down stairs, passing below two doors and partly resting on carpet and wood. A positive advantage is gained by resting the heavy wire in this manner, the words being clearer and more distinct, and free from the rumbling sound occurring with a suspended wire free to move about.

(4) Fastened No. 23 copper wire to telegraph-wire, made another and similar attachment 75 yards further on, but within two posts. Breathing, whistling, and tuning-fork sounds readily transmitted.

(5) Carried the latter attachment to 150 yards, thus *passing one post*. Breathing, whistling, singing, and the sound of the light C tuning-fork, formerly mentioned, readily transmitted. No apparent loss though passing the support (the latter was of the usual china-ware cup with binding-wire). The speaking was not so distinct, although the different word-sounds were discernible. This can be accounted for by the fact that, as the poles were about 14 feet high, the attachment-ends were free to swing about, which, combined with the exposed situation of the main line, gave rise to a considerable vibratory action due to other causes than the vocal sounds. (See diagram, page 293.)

(6) About 50 yards of No. 23 copper wire was laid out so

as to rest partly on grass, and fastened up at the ends to pins; attachments were made, and vocal sounds transmitted: whistling and the tuning-fork sounds very clearly heard, although a high wind was blowing at the time.



4. *The Mouth- and Ear-pieces.*—The mouth- and ear-pieces used in these experiments have been of various materials and forms. The materials tried have been pasteboard, wood, gutta-percha, india-rubber, parchment, iron, tin, and zinc. These have generally been arranged as disks or drums, having a more or less extended rim around them to confine the sounds. This rim has been of cylindrical, conical, and other forms.

In general, greater volume of sound accompanied increased depth of rim; but the sounds were hardly so distinct as when the rim was kept shallower.

The wire was usually attached to centre of disk; but in some cases good results were got where the wire was led through a cylindrical hollow piece of wood and terminated *close* to the disk; indeed a hollow piece of wood *without* a disk did very well.

As a rule, the effects seemed better when the wire was led outside of the house.

High-pitched voices are more easily heard than deep strong voices.

In the experiments with the telegraph-wire one of the disks used was of thin sheet-iron $3\frac{1}{2}$ inches in diameter. Set in a wooden rim about $\frac{1}{2}$ inch deep, the wire was fastened into a small piece of wood, which in turn was cemented down to centre of disk. The tuning-fork sounds were very well heard with this arrangement; and one peculiarity was that, on the wooden fastening accidentally breaking away from the iron, the sounds could again be heard by holding the disk in one hand and pressing the wooden termination of the wire upon the disk with the other.

5. *Wires*.—The wires, as a rule, require to be more or less tightened up; but this varies with the heaviness of the wire.

The sound is increased with a tight wire.

The volume of sound appears to be increased with a heavy wire. Thus in the telegraph-wire about $\frac{1}{8}$ inch thick, probably No. 8, the sounds were stronger and fuller than in the thinner wires, and, probably owing to the high tension of the former, faint sounds were more readily transmitted: thus the accidental or intentional touching of the tuning-fork with the rim of the mouth-piece, causing a slight clicking sound, was distinctly heard through the ear-piece at a distance of 150 yards—and this, even although the two attachments of copper wire were practically at right angles to the main wire, whereby part of the sound would pass away onwards up and down the line.

6. The great delicacy of the action may be inferred from the fact that fine sand strewn upon the disk of the ear-piece is unaffected by conversation through lengths of about 7 yards. The sensitiveness also of the mouth-piece was shown by sounds *not spoken into it* being readily transmitted, such as coughing, laughing, or remarks made by persons standing beside the instrument. Indeed, in some cases an advantage is obtained by keeping back from the mouth- or ear-pieces; and the author has sometimes thought an improvement was obtained by holding the ear-piece slightly inclined to the ear.

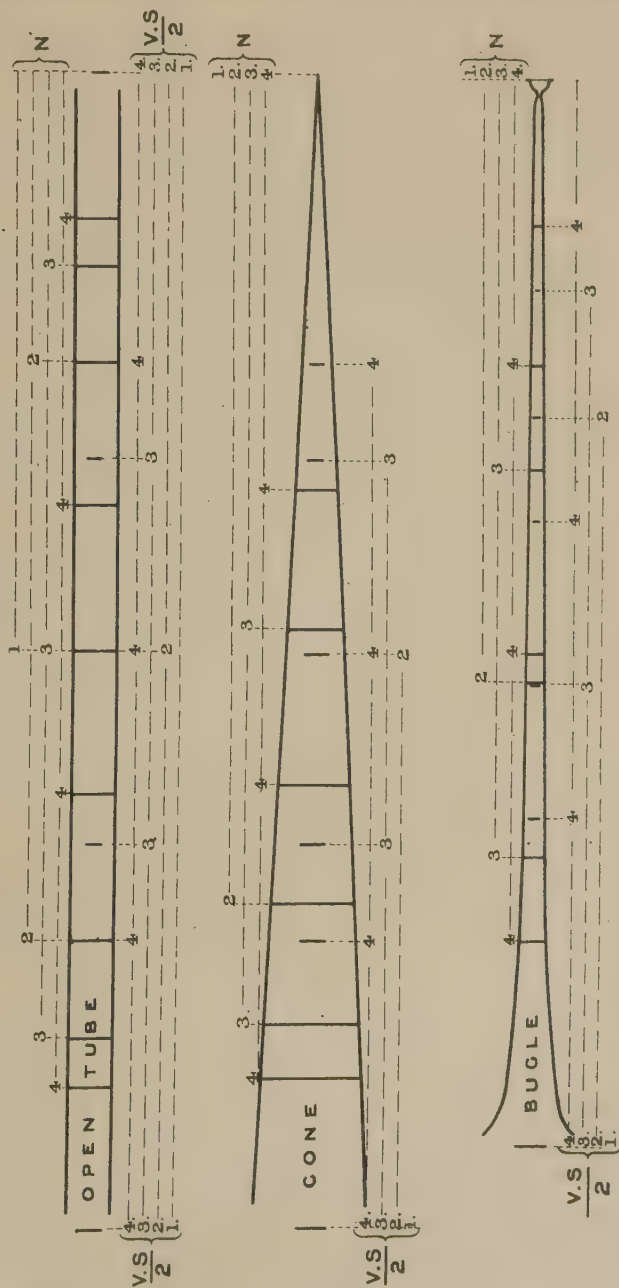
In all cases the individual voice could easily be distinguished though modified more or less by the structure and material of the mouth- and ear-pieces.

The mouth- and ear-pieces were usually of the same form and material, and were therefore used for either speaking or hearing. Some forms, however, do better as ear-pieces, others as mouth-pieces.

In conclusion, the author believes that many interesting physical questions may be studied by means of these arrangements, and that practical application may be made where communication of this nature is required.

NODAL POINTS.

Scale - $\frac{1}{8}$ full size.



XXXI. *The Electrical Properties of Bees'-wax and Lead Chloride.* By W. E. AYRTON, *Professor in the Imperial College of Engineering, Tokio, Japan.*

[Plate VII.]

IN the two papers by Prof. Perry and myself on Ice as an Electrolyte, recently read before the Physical Society, we showed that both the conductivity and specific inductive capacity of $\left\{ \begin{smallmatrix} \text{ice} \\ \text{water} \end{smallmatrix} \right\}$ increased regularly, without discontinuity, in passing from several degrees below the freezing point to several degrees above it. We drew attention to the fact that, in consequence of the absorbed charge in water being immeasurably greater than the surface-charge, we could not hope, by any method of experimenting, to properly compare the true specific inductive capacity with the index of refraction for light of infinitely long waves; so that, in fact, the only support that Prof. C. Maxwell's electromagnetic theory of light could hope to derive from these experiments must be based simply on the fact that in $\left\{ \begin{smallmatrix} \text{ice} \\ \text{water} \end{smallmatrix} \right\}$ both the specific inductive capacity and the index of refraction increase as the temperature rises. At the meeting of the Society on November 3rd, at which the second of our two papers was read, Prof. G. Foster mentioned that he had recently been collecting all the results he could find connecting specific inductive capacity with index of refraction. I therefore beg to forward, as a contribution to this collection, the following results of some further experiments which I have been making on this subject.

For the last two years my attention has been turned to wax as a good material for electrically testing, especially in regard to the connexion which, in our paper on the Viscosity of Dielectrics, communicated to the Royal Society, we pointed out existed between high specific inductive capacity and low specific resistance. I therefore had constructed a large condenser, consisting of many sheets of letter-paper soaked in melted bees'-wax, with alternate sheets of tin-foil. After

the condenser was built up in the usual way, melted bees'-wax was poured in, the plates squeezed together, and the whole shut up in a fairly good water-tight wooden box. The condenser was buried several feet under ground, to ensure uniformity of temperature, connexion being made with the insulated coating by a piece of Atlantic-cable core, and with the other coating by a piece of bare copper wire.

After this condenser had been buried for a short time underground, it showed the apparently abnormal condition of diminution of resistance by electrification. This phenomenon then formed the subject for special investigation with this condenser, an account of the results obtained being given at the end of this short paper.

As bees'-wax is one of the few substances in which the index of refraction for light increases in passing from the liquid to the solid state, it seemed important, in connexion with the electromagnetic theory of light, to carefully measure the specific inductive capacity of a wax condenser as it was gradually cooled through the solidifying point. A small, shallow, clean copper box, 19 centims. long by 17 centims. wide, was therefore lined with a sheet of letter-paper, 0·036 centim. thick, previously well soaked in melted bees'-wax. A clean copper disk, 12·8 centims. in diameter, was placed on the top, weighted down, and the dish filled up with melted wax. This condenser, A B (fig. 1), was heated in an oil-bath, C D. E and F are holes for the insertion of thermometers, of which the bulbs were just above the wax condenser; G is an opening through which the insulated electrode H of the condenser may protrude without touching the oil-bath. A wooden stand, W W, supports the condenser in the middle of the bath; and a glass vessel V holds strong sulphuric acid to keep the inside space artificially dry. The bath is closed by a double door, which is made to fit well by a strip of leather inserted between it and the bath.

The condenser having been inserted, the bath was heated to about 90° C., and kept at that temperature for some time; the lamps were then removed, when the temperature fell very slowly. The capacity was then measured (several observations being made at each temperature) by charging the condenser

with 75 Daniell's cells joined in series, and discharging it through an exceedingly delicate Thomson's reflecting galvanometer. The curves A B C D, E F G, H J K (fig. 2) represent the results obtained on three different days, distances measured parallel to O X representing temperature, the points O and X corresponding respectively with 0° C. and 100° C., and distances measured parallel to O Y representing capacity, the zero-line for capacity for the curves A B C D, E F G, being below O X by a distance equal to $\frac{2}{3}$ of O Y. For the curve H J K the zero-line is O X. It will be seen at once that these curves, obtained on different days, do not give the same capacity for the same temperature (the numbers, therefore, that have been calculated for the specific inductive capacity are not given); but considering, first, the very small capacities that had to be measured, and, secondly, the difficulty of accurately determining the temperature of a non-heat-conductor like wax, even when enclosed in the oil-bath, the discrepancies in the curves are not to be wondered at. One fact, however, is very striking in all the three curves; and that is the *rise* in capacity as the temperature very slowly falls from about 80° to 60° C., and the subsequent diminution in the capacity on a still further diminution of the temperature. Probably, had experiments on capacity been made when cooling from a much higher temperature, there would have been observed, first, a gradual diminution in capacity due to cooling down to about 80° C. (traces of this first diminution are seen in the portion A B of the curve A B C D); then we have the rise of capacity as the wax solidifies at about 60° C.; and, lastly, we see the subsequent rapid decrease on further cooling. Now this is precisely in agreement with the changes known to occur in the index of refraction for light; and hence the interest of these experiments.

As there was always a small electromotive force in the wax condenser, and as the vibrations of the galvanometer-needle were, as usual, damped by the air-vane, I used for calculating the capacity the formula developed by Prof. Perry and myself for employment in such cases*, which is

$$Q = \frac{H}{lG} \frac{P}{2\sqrt{\pi^2 + L^2}} \left[\left\{ (x_1 - x_r)^2 \epsilon^{\frac{2L}{\pi} \tan^{-1} \frac{\pi}{L}} - \frac{\pi^2}{\pi^2 + L^2} x_r^2 \right\}^{\frac{1}{2}} + \frac{L}{\sqrt{\pi^2 + L^2}} x_r \right],$$

* 'A Test for determining the Position of a partial Discontinuity, without Earth-fault,' by Professors W. E. Ayrton and John Perry, p. 12.

where Q is the quantity of electricity discharged through the galvanometer, H the horizontal intensity of the galvanometer-field, l the half length of the needle, G the galvanometer-constant, P the periodic time of vibration, L the logarithmic decrement, x_1 the first sudden swing on discharge, x_r the deflection that would be produced by the small constant current, and which is equal to

$$\frac{x_1 + Dx_2}{1 + D},$$

where x_2 is the second swing and D the decrement.

It might, of course, be at once objected that the rise in capacity as the wax cools from about 80° to 60° C. is perhaps not due to any change in the specific inductive capacity, but merely indicates that the distance between the copper plates of the condenser was slightly diminished by the wax shrinking on solidifying. This solution, however, is improbable, since, although a sudden expansion of the wax on solidifying (if such an expansion existed) might have separated the plates, it is unlikely that the contraction which really occurred could have brought them nearer together than the thickness of the paper by which they were separated when the wax was liquid. Nevertheless, partly to obtain additional evidence on this point, and partly to measure the specific resistance (or resistance per cubic centimetre) of bees'-wax at different temperatures, I made ten distinct sets of experiments, occupying many days, on the conductivity of wax. In these experiments the wax condenser was heated up to about 130° C., and a current sent through it with the 75 Daniell's cells in series. The temperature was kept constant at about 130° C. until the galvanometer-deflection had reached its maximum, when it was considered that the wax had acquired the temperature indicated by the thermometer. The temperature was then allowed to fall very slowly, and frequent readings of the galvanometer and thermometer were taken. The results obtained are shown on fig. 3, temperature being measured parallel to OX , the points O and X corresponding with 30° and 130° C.; distances measured parallel to OY represent conductivity on such a scale that for the curve LM , representing the conductivity between 115° and

65° C., O S corresponds with a resistance of 67,735 megohms per cubic centimetre ; and for the curves N P, Q R (which are drawn on a larger scale) the distance O T represents a resistance of 186,000 megohms,—the zero-line for conductivity for all three curves being O X. The point P, corresponding to a resistance of 37,000,000 megohms per cubic centimetre, represents the lowest conductivity I was able to measure with certainty directly with the galvanometer. It may here be mentioned that such high resistances could be measured with the galvanometer, since one Daniell's cell, through a resistance of 600 megohms, gave 130 scale-divisions deflection on a scale about $1\frac{1}{2}$ metre distant. The various curves obtained for conductivity between 115° and 65° C. agree so closely that they may all be represented by the one curve L M. The curves for the conductivity between 80° and 40° C. are all quite regular, but not all of exactly the same slope, the difference depending on the highest temperature to which the wax was heated before cooling on the particular day of experimenting, this being sometimes about 130° C. and at other times about 90° C. All the curves, however, agree so closely that they are all contained between the two limiting curves N P and Q R shown in fig. 3. In no curve was there *the slightest appearance* of a rise of conductivity at the melting-point, which would probably have been obtained had the copper plates approached one another an appreciable distance on the wax solidifying.

We may therefore conclude that in the previous experiments the rise in the capacity in solidifying indicates a true increase in the specific inductive capacity coincident with an increase in the index of refraction for light.

As regards apparent increase of resistance by electrification, which, as mentioned, I observed during repeated experiments, extending over some months, with the wax condenser buried underground, the general conclusions arrived at were that not only did the conductivity usually increase by electrification, but that it steadily increased day by day—a result indicating that the wax was deteriorating, probably from damp penetrating through the joints of the wooden box in spite of leather having been inserted between the different parts of the wood before they were screwed together. This conclusion appeared to be correct, since, on digging up the condenser and keeping it

near a fire for many days, it regained its original high resistance. The damp must therefore not only have entered through the joints in the wood, but through some small cracks that were observed in the mass of wax when the condenser was opened ; and it was probably due to this damp that the peculiar effects of polarization were observed similar to those noticed by the Comte du Moncel when testing stones, and by Mr. T. Warren in certain insulating oils.

I now made a number of experiments with lead chloride as a dielectric—a substance to which my attention was especially drawn by some remarks of M. Buff in *Ann. Chem. Pharm.* cx. p. 258 (1859), in which he says that this substance conducts electricity like a metal (that is, without decomposition)—a conclusion, however, which at first sight would appear to be negatived by certain experiments of M. Wiedemann published in *Pogg. Ann.* cliv. 318–320, from which he found that the resistance of lead chloride diminished by increase of temperature.

I first had made a small carbon box containing a carbon plate, but prevented from touching it by three small pieces of clean glass. The carbon plate had a carbon electrode attached to it, the whole being cut out of a solid piece of carbon so as to have the shape of an inverted T. Into the box lead chloride was poured in a fused state until it covered up the plate, but leaving the carbon electrode of the plate protruding for connexion with the battery. The whole was then allowed to cool very slowly. The outer part of the carbon box and the end of the carbon electrode were now electrotyped, and copper wires soldered on, the junctions of the carbon and copper being quite clear of the lead chloride.

With this condenser the results given on the next page were observed.

In addition to the resistance of the condenser being measured while the battery was connected, time-readings were also taken with the galvanometer of the discharge from the condenser after the removal of the battery, as well as time-readings with an electrometer of the electromotive force in the condenser producing the discharge. As, however, the diminution in the discharge-deflection was in each case quite regular, the curves are not given.

No. of exp.	Date.	Temp.	Battery.	Resistance of the wax condenser, in megohms,				Remarks.
				after 15 sec.	after 30 sec.	after 1 min.	After	
1.	Nov. 13th ...	18° 8 C.	{ 31 volts copper pole to carbon box	7.97	8.077	7.875	14 min., 6.774	{ Steady diminution in resistance from the middle of the first minute.
2.	Nov. 13th ...	18° 8 C.		.....	7.848	8.153	14 min., 6.326	{ Steady diminution in resistance from the end of the third minute.
3.	Nov. 14th ...	19° 9 C.		.....	10.15	9.706	5 min., 8.682	{ Steady diminution in resistance from the first observation.
4.	Nov. 15th ...	18° 5 C.	{ 30 volts copper pole to carbon box	9.254	9.118	9.323	8 min., 7.607	{ Steady diminution in resistance from the end of the first minute.
5.	Nov. 21st ...	.....		5.477	5.128	5.128	14 min., 3.951	{ Steady diminution in resistance from the beginning.
6.	Nov. 24th ...	.....		4.874	5.770	.....	12 min., 4.365	{ Steady diminution in resistance from the middle of the second minute.
7.	Nov. 26th ...	.....	{ 30 volts copper pole to carbon plate ...	5.755	6.167	6.167	8 min., 5.820	{ Steady diminution in resistance from the beginning of the second minute.
8.	Nov. 27th ...	.....		5.911	6.186	5.911	9 min., 4.708	{ Steady diminution in resistance from the middle of the first minute.
9.	Nov. 28th ...	.....		6.174	6.174	6.174	6 min., 5.409	{ Steady diminution in resistance from the beginning of the second minute.
10.	Nov. 29th ...	.....	{ 30 volts copper pole to carbon box .....	.....	.....	6.476	6 min., 5.440	{ Steady diminution in resistance from the beginning of the second minute.
11.	Nov. 30th ...	.....		7.875	8.100	7.875	10 min., 6.163	{ Steady diminution in resistance from the middle of the first minute.
12.	Dec. 1st .....	.....		8.621	8.493	8.129	5 min., 7.295	{ Steady diminution in resistance from the commencement.

Condenser well discharged between every two tests.

It is interesting to observe in the Table (p. 303) that in *every* case there is a diminution of resistance by electrification, although in some cases there was an increase during the first minute. Looking at the first group of tests, taken between November 13th and 15th, we see a gradual increase in the resistance day by day. Looking also at the second group made between November 21st and December 1st, we likewise see a steady daily increase in the resistance ; but in the interval between November 15th and 21st, when no tests were made , there appears to be a decided diminution in resistance. Considering, however, that the tests taken on November 13th, at the beginning, and on December 1st, at the end of the investigation, give almost identical results, it cannot be concluded with certainty that there was any decided deterioration taking place in the lead chloride. But on breaking up the condenser, the lead chloride was found to contain many small holes ; so that it is possible that damp may have collected in these. This solution, however, would at first sight appear to be rather improbable ; since the condenser, both when being tested and when not tested, remained in an atmosphere kept partially dry with sulphuric acid.

Some fresh lead chloride was prepared in the same way as before—that is, by precipitating from a solution of lead acetate with a solution of common salt, and carefully washing the precipitate several times with distilled water. But the new condenser, made with the carbon box and plate, was found to have a resistance of only two megohms at 16° C.; and, unlike what was experienced in the former case, the resistance in all the experiments was now found to increase by electrification. This, however, is probably explained by the fact that, whereas in the previous case thirty volts electromotive force was used, now only one volt was employed ; so that decomposition (whether of the lead chloride itself, or of the damp which after decomposition may act on the chloride) was probably not produced. Some preliminary temperature-tests were now made ; and, in accordance with Wiedemann's results, I found that the resistance diminished with elevation of temperature.

The condenser was now left in an atmosphere dried with sulphuric acid from December 21st to January 7th, when it was found that the resistance had increased to about 15·6

megohms at 70°C . A large number of measurements of the conductivity at different temperatures, using the same oil-bath for raising the temperature as is shown in fig. 1, were now made. The different experiments gave results so nearly agreeing that they may all be represented by the curve STV (fig. 4), in which distances parallel to OX represent temperature, the points O and X corresponding to the temperatures 0° and 100°C . respectively; and distances parallel to OY represent conductivity on such a scale that the point T, corresponding to a temperature of 70°C ., represents a resistance of about 15.6 megohms. The curve is approximately logarithmic; that is, the ratio of the difference of the logarithms of the conductivities to the difference of temperatures is approximately constant.

Thinking that possibly the method previously employed for making the lead chloride, by precipitating it from a solution of lead acetate with a solution of common salt, may have introduced traces of some salt of lead other than the chloride, the following method was now employed for making another supply of the chloride. From a clear solution of lead nitrate a precipitate was formed with colourless hydrochloric acid, and the precipitate well washed with distilled water. A third condenser was now constructed, three small pieces of glass 0.225 centimetre thick being used to separate the carbon plate from the box. The connexions with the box and plate were made as before, by first electrotyping the carbon with copper and then soldering on copper wires, the junctions of the carbon and copper not being in contact with the lead chloride. A condenser was also made with a copper box and a copper plate, the two being well coated with graphite to protect them from the action of the lead chloride, and separated from one another by three small pieces of glass 0.135 centimetre in thickness.

Tests of conductivity were now made at different temperatures with both condensers, 0.075 volt being employed with the carbon and 7.5 volts with the copper condenser, or sometimes 2.2 volts with the latter. With the carbon condenser and with the smaller electromotive force the resistance was found to increase with electrification, whereas with the copper condenser and with the electromotive force 2.2 volts the re-

sistance diminished with electrification, and with 7·5 volts this diminution became much more rapid, these results being observed at both high and low temperatures. In the earlier experiments with this copper condenser the diminution was regular, whereas later on it proceeded irregularly; but on the whole it may be said that when an electromotive force not exceeding $1\frac{3}{4}$ volt was employed there was an increase in resistance by electrification, such as is usually experienced with gutta-percha and with ordinary dielectrics, while when the electromotive force exceeded this limit there was either a regular or an irregular diminution of resistance by electrification—the results apparently not depending much on whether carbon or copper coated with graphite was used for the plates of the condenser.

As this limiting electromotive force appears to be about the same as that necessary to decompose water, I think we may fairly conclude that the diminution in resistance is due to a decomposition of the damp (which appears to be contained in the lead chloride even when careful means are taken to dry it), and to the products of the decomposition acting on the chloride. Fig. 5 shows four electrification-curves, A A A, B B B, C C C, D D D, obtained from four *successive* experiments with the carbon box, and corresponding with the temperatures 15°C. , 57°C. , 14°C. , 61°C. respectively. Time is measured parallel to O X, the points O and X corresponding to the moment of applying the battery, and to 50 minutes afterwards; conductivity is measured parallel to O Y from the line O X of zero conductivity. The curves B B B and D D D, for 57°C. and 61°C. , are drawn on a vertical scale five times smaller than that employed for A A A and C C C—the scale for time, however, remaining the same. All the tests from which these curves are drawn were made with 0·075 volt electromotive force. The curves *aaa*, *bbb*, *ccc*, fig. 6, are the discharge-curves obtained in the three above experiments for 15°C. , 57°C. , and 14°C. , observations of the discharge in the experiment for 61°C. not having been taken. The scale both for conductivity and for time is the same exactly as that employed in the curves A A A, C C C, fig. 5. All the curves show a regular increase of resistance with electrification, the increase being far more rapid at a high than at a low tempe-

rature. As was seen from the curve S T U, fig. 4, so also from fig. 6 we learn that the conductivity is much greater at a high than at a low temperature; and we also see from the curves A A A, B B B, C C C, D D D, that the general effect of testing day by day appears to lower the conductivity.

Electrification-curves E E E, F F F, G G G, H H H, fig. 7, were obtained from four *successive* tests with the copper-box condenser, and correspond with the temperatures 15°C ., 60°C ., 13°C ., 61°C . respectively. Time is measured parallel to O X, the points O and X corresponding to the moment of applying the battery; and 50 minutes afterwards conductivity is measured parallel to O Y from a zero as far below O X as the point Y is above. Curve F F F is on a scale for vertical distances one twentieth of that employed for the curves E E E G G G, and H H H on a scale one fifth of that used with E E E, G G G: that is to say, if the same scale were employed for vertical distances for all four curves, the two for the higher temperatures would be far above those for the lower temperatures—in fact, would be off the paper altogether. For horizontal distances (that is, for time) the same scale is employed for all the curves. An electromotive force of 7.5 volts was employed with all the experiments from which these four curves were drawn. Although the curves are irregular, still, on the whole, there is an increase of conductivity or diminution of resistance with electrification; and that this is probably due to the chemical action of the current referred to above is shown from the irregularity of the discharge-curve *g g g* obtained after removing the battery in the test at 15°C . Curve *h h h*, however, which is the discharge-curve for the test at 61°C ., does not show any such irregularity; but then it must be noticed that H H H, the charge-curve for this temperature, indicates on the whole rather an increase than a diminution of resistance by electrification.

I have to thank three of my students, Messrs. Asano, Fujioka, and Nakano, for valuable assistance rendered during the course of this investigation.

April 1st, 1878.

XXXII. *Recent Researches in Solar Chemistry.**By J. N. LOCKYER, F.R.S.**

THE work which is now being done in the various new fields opened up in connexion with solar studies may be conveniently divided into three perfectly distinct branches. We have, first, that extremely important branch which has for its result the complete determination of the position of every thing which happens on the Sun. This, of course, includes a complete cataloguing of the spots on the sun which have been observed time out of mind, and also of those solar prominences the means of observing which have not been so long within our reach. It is of the highest importance that these data should be accumulated, more especially because it has been determined that both in the case of spots and prominences there are distinct cycles, which may in the future be very much fuller of meaning to us than they seem to be at present.

This brings me to refer to the second branch of the work ; and it is this :—These various cycles of the spots and prominences have long occupied the attention both of meteorologists and magneticians ; and one of the most interesting fields of modern inquiry, a field in which very considerable activity has been displayed in the last few years, is one which seeks to connect these various indications of changes in the sun with changes in our own atmosphere. The sun, of course, is the only variable that we have. Taking the old view of the elements, we have fire represented by our sun, variable if our sun is variable. Earth, air, and water, in this planet of ours we must recognize as constants. From this point of view, therefore, it is not at all to be wondered at that both magneticians and meteorologists should have already traced home to solar changes a great many of the changes with which we are more familiar. This second branch of work depends obviously upon the work done in the first, which has to do with the number (the increasing or decreasing number) of the spots and prominences, and the variations of the positions which these phenomena occupy on the surface of the sun. As a result of this work, then, we shall

* Read May 11, 1878.

have a complete cataloguing of every thing on the sun, and a complete comparison of every thing on the sun with every meteorological phenomenon which is changeable in our planet.

When we come to the third branch of the work, the newest branch, things are not in such a good condition. The workers are too few ; and one of the objects of any one who is interested in this kind of knowledge at the present moment must be to see if he cannot induce other workers to come into the field. The attempt to investigate the chemistry of the sun, even independently of the physical problems which are, and indeed must be, connected with chemical questions, is an attempt almost to do the impossible unless a very considerable amount of time and a very considerable number of men be engaged upon the work. If we can get as many workers taking up various questions dealing with the chemistry of the sun as we find already in other branches, I think we may be certain that the future advance of our knowledge of the sun will be associated with a future advance of very many problems which at the present moment seem absolutely disconnected from it.

I have today to limit myself to this chemical branch of the inquiry ; and first let me begin by referring to the characteristics of the more recent work with which I have to deal. Here, as in other branches of physical and chemical inquiry, advance depends largely upon the improved methods which all branches of the science are now placing at the disposal of all others. Our knowledge of the chemical nature of the sun is now being as much advanced by photography, for instance, as that descriptive work of which I spoke in the first instance (which deals with the chronicling and location of the various phenomena) has, in its turn, been advanced by the aid of photography. I do not know whether the magnificent results recently obtained by Dr. Janssen have been brought before this Society ; but the increase in photographic power recently secured by Dr. Janssen is one which was absolutely undreamt of only a few years ago. It is now possible to record every change which goes on on the sun down to a region so small that one hardly likes to challenge belief by mentioning it. Changes over regions embracing under one second of angular magnitude in the centre of the sun's disk can now be faithfully recorded and watched from hour to hour.

One of the advantages which has come from the introduction of the new apparatus has been the possibility of making maps, on a very large scale, of the solar lines and of the metallic lines which have to be compared with them. Thanks to the great generosity of Mr. Rutherford, who is making the most magnificent refraction-gratings which have ever been seen, and who is spreading them broadcast among all workers in science, one has now easy means of obtaining with inexpensive apparatus a spectrum of the sun, and of mapping it on such a scale that the full magnification of the fine line of light which is allowed to come through the slit will form a spectrum the half of a furlong long : an entire spectrum on this scale, when complete (as I hope it some day will be, though certainly not in our time) from the ultra-violet, already mapped by Mascart and Cornu, to the ultra-red, which has quite recently for the first time been brought under our ken by Captain Abney, will be 315 feet long. This is a considerable scale to apply to the investigation of these problems ; but recent work has shown that, gigantic as the scale is, it is really not beyond what is required for honest patient work. I have already had an opportunity of bringing before the Physical Society several of the methods in use for comparing the spectra of the various elementary bodies with that of the sun. It is not, therefore, necessary now to refer to them. There are, however, others of recent application which are of very considerable importance.

When, instead of inquiring into the coincidence of the metallic lines, we wish to determine the coincidence of the lines due to various gases, the method hitherto employed has been to enclose the gases in Geissler tubes, to reduce their pressure, and in that way to fine down the lines. The importance of this apparently small matter can be very well demonstrated by an experiment easily arranged in an electric lamp, which sodium enables us to perform without any great difficulty. The point of this experiment is that, if we vary the density of any vapour, we vary sometimes to a very considerable extent the thickness and intensity of the lines. I am about to throw the spectrum on a small screen which I have behind the lamp ; and I hope I shall succeed in rendering the phenomena visible. I want you to observe the variation in the thickness of the reversed

line of sodium. Every turn of the screw which raises or lowers the upper pole, enables me to vary to a very considerable extent indeed the thickness of that absorption-line.

Now the way in which that has been managed is very simple. The only arrangement required is one which shall enable me at will to vary the density of the sodium-vapour. When I make the sodium-vapour as dense as possible, then the line is very thick. When I make it much less dense, the line becomes thinner. If the spectrum on the screen had been a gas-spectrum (supposing it were possible to exhibit a gas-spectrum to an audience), the exact equivalent of that experiment would have been, that the gaseous spectrum at atmosphere pressure would have given us most of the lines as thick as the sodium-line was at its thickest; while if by any possibility we could have rendered the phenomena visible while the pressure was being reduced, as the pressure of the gas was reduced the line would thin. Now there are very great objections to the using of Geissler tubes. One very valid objection is that the gas becomes much less luminous as its pressure is reduced.

Here is a method which is excellent in this way, that it enables all the work connected with gaseous spectra to be done at atmospheric pressure, and we get the line down as thin as we choose, *not by reducing the pressure, but by reducing the quantity of gas in a mixture*. If we take, for instance, a spark in ordinary atmospheric air and observe its spectrum, we find the lines of the constituents of atmospheric air considerably thick; but if I wish to reduce the lines, say of oxygen, down to a considerable fineness so that I can photograph its lines (these should be fine, in order to enable me to determine their absolute position; to accomplish this) the spark is made to pass in a glass vessel with two adits and one exit tube. If I wish to observe the oxygen-lines fine, I flood the vessel with nitrogen so that, say, there is only 1 per cent. of oxygen present, and observe the current between the enclosed electrodes. If I wish to observe nitrogen-lines fine, I flood it with oxygen, so that there is only 1 per cent. of nitrogen present. In this way, by merely making an admixture in which the gas to be observed is quantitatively reduced, so that the lines which we wish to investigate are just visible in their thinnest state, we have a perfect means of doing this without any apparatus depending on the

use of low pressures ; and those who have worked most with Geissler tubes will appreciate the very great simplicity of work which is thus introduced.

Another important application of spectroscopic theory recently applied to the investigation of the chemistry of the sun is this :—Assume that the spectrum of any substance is not a pure spectrum of that substance, but of that substance as it generally exists in an impure state.

The spectrum will be found rich in lines ; and when very considerable care is employed, one may go away with the idea that in iron, for instance, all the lines which are observed in the spectrum of iron coincident with Fraunhofer lines represent coincidences in the case of each line with iron in the sun and iron in our laboratory. But the more the work is carried on, the more one finds that the complex spectra which are observed are really much more simple when all the impurities are taken into account.

In the region of the solar spectrum, for instance, recorded on the map exhibited we have a great many iron-lines ; but before the method of determining impurities was utilized, the spectrum was very much richer than it is at present ; possibly one fourth of the lines have been withdrawn. In every specimen of iron which has been used in this work the lines of calcium, aluminium, and some of the lines of manganese and cobalt have been represented ; and no chemist will wonder at this result. But there is a very curious thing which chemists, I think, will wonder at. In this part of the spectrum there were two lines which, by their thickness both in the solar and iron spectra, seemed undoubtedly to belong to iron ; but further inquiry led to this extraordinary result—that one of these lines in all probability has its origin in the vibration of molecules of tungsten, the other being probably a line of molybdenum. Glucinum is another metal which may be referred to in this connexion ; and it would appear that it is almost impossible to get a specimen of iron which does not contain, not only calcium and aluminium, but others which we consider rare metals on the earth, such as tungsten, molybdenum, and glucinum.

A few years ago, taking the work of Kirchhoff, Bunsen, Angström, and Thalén into consideration, and connecting it, so far as one could connect it, with those ideas of which recent

eclipses have been so fruitful, our chemical view of the sun's atmosphere was one something like this :—We had, let us say, first of all an enormous shell of some gas, probably lighter than hydrogen, about which we know absolutely nothing, because at present none of it has been found here ; inside this we have another shell, of hydrogen ; inside this we have another shell, of calcium, another of magnesium, another of sodium, and then a complex shell the section of which has been called the reversing layer, in which we get all the metals of the iron group plus such other metals as cadmium, manganese, titanium, barium, and so on. The solar atmosphere, then, from top to bottom, consisted, it was imagined, of a series of shells, the shells being due not to the outside substance existing only outside, but to the outside substance extending to the bottom of the sun's atmosphere, and finding in it at a certain height another shell, which again formed another shell inside it, and so on ; so that the composition of the solar atmosphere as one went down into it, got more and more complex : nothing was left behind ; but a great many things were added.

The recent work, so far as I am acquainted with it, has not in any way upset that notion ; but what it has done has been to add a considerable number of new elements to this reversing layer. Instead of consisting of 14 elements, as it was then found to do, it may be, I think, pretty definitely accepted now to consist of about thirty.

The metals considered to be solar as the result of the labours of Kirchhoff, Ångström, and Thalén together with the considerations brought forward regarding the length of the lines, were as follows:—

Na	Fe	Ca	Mg	Ni
Ba	Cu	Zn	Cr	Co
H	Mn	Ti	Al	

Those more recently added, with the evidence by which their existence in the solar atmosphere is rendered probable, are as follows (in the Tables, pp. 315–317).

It is important to bear in mind that the lines recorded in these Tables are in most cases the very longest visible in the photographic region of the respective spectra ; in some cases they are limited to the region 39–40, which I have more especially studied ; so that the fact of their being reversed

Metals the presence of which in the Sun is confirmed.

Name of metal.	Approximate W.L. of lines reversed in the solar spectrum.	Observations.	By whom previously mapped.	Particulars from Thalen's Tables.		
				Metal.	Wave-length.	Intensity. 1 = brightest.
Strontium	4029·60	Absent from spectre normal, near long Mn line ...	New line.	Sr	4078·5	1
	4076·77	A line at 4076·9 in spectre normal assigned to Ca...	Thalén.....	Ca	4077·0	3
	4215·00	In spectre normal assigned to Ca, W.L. 4215·40...	Thalén.....	Sr	4215·3	1
	4607·50	A line at 4604·5 in spectre normal assigned to Ca	Thalén.....	Ca	4215·3	1
Lead	4019·28	Absent from spectre normal	New line.	Sr	4607·5	1
	4056·80	An unassigned line near required position (W.L. 4057·25) in spectre normal		Ca	4607·5	4
	4061·25	Absent from spectre normal		Pb	4058·0	4
				Pb	4062·5	4
Cadmium	4677·00	An unassigned line at W.L. 4676·5 in spectre normal.....	Thalén.....	Cd	4676·8	1
	4799·00	An unassigned line at W.L. 4798·9 in spectre normal ..	{ Kirchhoff... Thalén..... Kirchhoff... }	Cd	4799·0	1
Potassium	4042·75 4046·28	Absent from spectre normal	New line.			
Cerium	3928·7 4012·0	Absent from spectre normal	New line.			
			New line.			
Uranium	3931·0 3943·0 3965·8	Absent from spectre normal	New line.			
		Close to Al line	New line.			
		Absent from spectre normal	New line.			

Name of metal.	Approximate W.L. of lines reversed in the solar spectrum.	Observations.	By whom previously mapped.	Particulars from Thalén's Tables.			
				Metal.	Wave-length.	Intensity. 1 = brightest.	
Vanadium	3901·3	Assigned by Ångström to Ca Absent from Ångström's map Assigned by Ångström to Ca Assigned by Ångström to Ca	New line.	{ Ca Va Va Ca Va Ca Va }	4379·1 4379·0 4384·0 4389·4 4389·0 4407·0 4407·5	4 1 1 4 2 5 1	
	3909·3		New line.				
	3989·65		New line.				
	3992·5		New line.				
	3997·9		New line.				
Palladium	4379·0	Thalén.....	Thalén.....	{ Pd Fe Pd Pd Pd }	4787·0 4785·8 4817·0 4874·0	3 5 3 3	
	4384·0	Thalén.....	Thalén.....				
	4389·0	Thalén.....	Thalén.....				
	4407·5	Thalén.....	Thalén.....				
		Thalén.....	Thalén.....				
Molybdenum ...	3893·0	Assigned by Ångström to Fe Not allocated by Ångström..... A line near required position assigned by Ångström to Fe	New line.	{ Mo Fe Mo Mo Mo Ni Ni }	4706·5 4706·5 4730·5 4818·0 4829·5 4828·4 4830·2	4 5 4 4 4 5 5	
	3958·0		New line.				
	4787·0		Thalén.....				Thalén.....
	4817·0		Thalén.....				Thalén.....
	4874·0		Thalén.....				Thalén.....
Molybdenum ...	3902·0	Very near Fe line. Not allocated by Ångström..... Assigned by Ångström to Fe Assigned by Ångström to Fe Absent from Ångström's map Line near assigned by Ångström to Ni	New line.	{ Mo Fe Mo Mo Mo Ni Ni }	4706·5 4706·5 4730·5 4818·0 4829·5 4828·4 4830·2	4 5 4 4 4 5 5	
	4576·0		New line.				
	4706·0		Thalén.....				Thalén.....
	4730·0		Thalén.....				Thalén.....
	4818·0?		Thalén.....				Thalén.....
4829·0?	Thalén.....	Thalén.....					

Metals probably present in the Sun (*continued*).

Name of metal.	Approximate W.L. of lines reversed in the solar spectrum.	Observations.	By whom previously mapped.	Particulars from Thalén's Tables.		
				Metal.	Wave-length.	Intensity. 1 = brightest.
Indium {	4101·0	Apparently coincident with Fe line in solar spectrum	Thalén..... Thalén.....	In	4101·0	1
	4509·0	Absent from Ångström's map		In	4509·5	1
Lithium.....	4603·0	The line in Ångström's map is placed at W.L. 4601·7 and no metal assigned	Thalén.....	Li	4602·7	1
Rubidium	4202·0	The line in Ångström's map is placed at 4201·0 and made winging the adjacent Fe line	Thalén.....	Rb	4202·0	2
Cæsium {	4554·9	Assigned by Ångström to Fe; no line in Thalén in this position	New line. New line.			
	4592·0	Absent from Ångström's map				
Bismuth.....	4722·0	Absent from Ångström's map	Thalén.....	Bi	4722·0	1
Tin.....	4524·0	Not in spectre normal, a neighbouring Bi line at 4524·4 is shown	Thalén.....	Sn	4524·0	1
Lanthanum {	3948·2	Not in spectre normal	New line. New line. New line.			
	3988·0	Not in spectre normal				
	3995·04	Not in spectre normal				
Glucinum	3904·75	Not in spectre normal	New line.			
Yttrium or Erbium {	3949·6	Not in spectre normal	New line. New line.			
	3981·8	Not in spectre normal				

in the solar spectrum must be considered the strongest evidence obtainable in favour of the existence in the sun of the metals to which they belong, pending the complete investigation of their spectra.

Where, however, there is only one line, as with Li, Rb, &c., the presence of these metals in the sun's reversing layer can, for the present, only be said to be probable. Neither must it be forgotten that, in addition to the long lines which a spectrum may contain in the red, yellow, or orange, long lines may exist in the hitherto unexplored ultra-violet region; so that the necessity for waiting for further evidence before deciding finally upon the presence or absence of such metals in the sun will be rendered obvious. •

It will be thought remarkable that, if the long lines of such metals as lithium and rubidium are found in the photographic region of the spectrum, the long lines Li W.L. 6705, Rb W.L. 6205 and 6296 should have escaped detection.

To this it may be replied that, although these red lines may be apparently the brightest to the eye, it by no means follows they are the longest, since they are situated in a part of the spectrum which affects the visual organ more strongly than the photographic region does. It is possible also that the reasoning I have lately used in a paper communicated to the Royal Society, on the spectrum of calcium, may be applied in these cases.

Since a sensitized film is affected by some rays more strongly than by others, in determining the lengths of lines from a photograph it is not fair to compare together portions of the spectrum separated by too great an interval.

Furthermore, the fact of these red lines having been overlooked in the solar spectrum is not conclusive proof of their absence, inasmuch as this portion of the spectrum is both brighter and less refrangible, and a greater degree of dispersion would be necessary when prisms are employed to render visible faint dark lines which are easily detected in the photographic region.

At present, then, out of the fifty-one metals with which we are acquainted here, more than thirty are known to exist in the sun with more or less certitude. Now it was a very remarkable thing that although such metalloids as carbon and

sulphur, iodine, bromine, and the like, had been very diligently searched for, no trace whatever had been found of them, giving any evidence that they existed together with the metals in these zones (these shells) to which I have referred.

Some years ago evidence was brought forward of the possible existence of the metalloids as a group outside the metals; and the evidence for this suggestion was of the following nature:—Independently of any questions connected with solar physics, I think all students of science now agree that the vapours of the various elementary bodies exist in different molecular states; if these different molecular states are studied by means of the spectroscope, perfectly different spectroscopic phenomena present themselves. If we use a large coil, we can drive every chemical substance with which we are acquainted, including carbon and silicon, into a molecular grouping competent to give us what is called a line spectrum, the spectrum with which we are most familiar when we use metals or salts of metals in the electric arc.

If, however, other conditions are fulfilled; if these bodies are not so roughly handled—if, in other words, we employ a lower degree of heat, or if we use electricity so that we get quantity instead of tension, then these line spectra die away altogether, and we have a spectrum, so called, of channelled spaces or flutings. Perhaps it will be convenient that I should throw one of these spectra on the screen, and point out exactly the difference to which I refer. I will first call attention to a line spectrum. Those lines are due to the vibrations of molecules of calcium and aluminium. The flutings which I now throw on the screen are perfectly different in appearance; in this case they have been produced by the vibrations of carbon at exactly the same temperature at which we get the line spectrum from aluminium and calcium.

Now, while we got these thirty-three metals to give us line spectra coincident with Fraunhofer lines, the only evidence (very doubtful evidence) of the existence of the metalloids in the sun at all, depended on the fact that, in the case of iodine and chlorine, some of the channelled spaces observed in their spectra at a very low temperature were imagined to be traced among the Fraunhofer lines in the spectrum of the sun. It is four years ago since evidence was gathered of a more con-

clusive kind in the case of carbon. The kind of evidence will be sufficiently indicated by throwing a comparison of the solar and carbon spectra on the screen. Below we have the bright flutings due to carbon-vapour; and above the solar spectrum this photograph includes a part in the ultra violet. When this negative is placed under a magnifying-glass, we find that most of the very delicate lines constituting the fluting in the bright portion have their exact equivalents among the Fraunhofer lines. This is the best-established piece of evidence, so far as I know, which seems to indicate that we have truly some of the metalloids present in the atmosphere of the sun by the coincidence of their spectra with the Fraunhofer lines. Further, carbon at all events exists under such conditions that its molecular structure is very much more complex than that of the metals in the reversing layer; and therefore it is probably withdrawn from the excessive heat of the lower region occupied by the reversing layer, which is competent, as we know from other considerations, to drive even carbon and silicon into the line-stage, supposing carbon and silicon to be there.

This branch of the work to which I have just referred, a branch which enables us to say that such a temperature must exist in such and such a region of the solar atmosphere, depends, in the main, upon questions raised by the differences between the spectra of certain bodies in the sun and in our laboratories. If, for instance, one wishes to observe the coincidence between, let us say, iron and the sun, iron is placed in the electric lamp; its spectrum is photographed: side by side with it we have the spectrum of the sun also photographed; and, as a rule (I say as a rule; but this is not absolute in the case of such metals as iron), the intensity of the iron-lines which we get in our laboratories is equivalented by the intensity of the so-called iron-lines which we assume to exist in the spectrum of the sun. That is the great argument, in fact, for the existence of iron in the sun. But when we leave the iron group of metals, we find others in which this coincidence, this great similarity of intensity from one end of the spectrum to the other, is very considerably changed. We get in the case of calcium very thick lines of calcium corresponding with very thin lines in the sun, and we get thin lines of calcium corresponding with very thick lines in the sun. In

fact, the two thickest lines which have already been mapped in the spectrum of the sun are lines due to calcium. If we photographed the spectrum of calcium with a very weak arc in that electric lamp, they would scarcely be visible at all. If, however, we pass from the tension of the arc to the tension which is obtainable with the use of a very large coil, then we can make the spectrum which we get artificially correspond exactly with the spectrum with which the sun presents us naturally; and the more we increase the tension (the larger the coil and the larger the jar we employ), the more can we make our terrestrial calcium vibrate in harmony, so to speak, with the calcium which occupies a very definite region in the atmosphere of the sun. Now this gives us this very precious teaching:—We know that the vapour of *calcium* occupies such and such a position in the sun; we know that to get the two things in harmony, as I said before, we must employ a very large induction-coil; and we know, again, that if we do employ a large induction-coil, all these beautiful flutings in the *carbon*-spectrum which have been thrown on the screen disappear utterly. That kind of carbon is no longer present in the reaction; but instead of it we have a new kind of carbon which is only competent to give us bright lines. We know, fourthly, that those bright lines do not exist reversed in the spectrum of the sun. Therefore the carbon must exist higher than the calcium, in a region of lower temperature.

In what I have said up to the present moment (and I have just touched very slightly on the physical side of the work, because I believe that in the future it will be most rich in teachings of the kind I have indicated), I must remind you that I have dealt solely with the Fraunhofer lines. Now it is knowledge ten years old, that if we observe the solar spectrum with that considerable dispersion which is now, I think, imperative if we are to do much good with it, there are bright lines in the ordinary solar spectrum side by side with the dark ones.

In a paper communicated to the Royal Society in 1868 I find these words:—"Attention has recently been drawn to certain bright regions in the ordinary spectrum." The position of these bright lines in the ordinary spectrum was then stated, and attention was called, among others, to one between *b* and

F. I call especial attention to that line now because the requisite amount of dispersion is now so common that any one, whenever the sun shines, may turn to *b* and see that bright line for himself. It will be found just as much outside the fourth line of *b* as the third line is on the other side of it. This bright line, lying in the most visible part of the spectrum, is exactly similar to many others, some of them in the yellow and some of them in the red. A careful list of these lines was made some years ago; and, I am sorry to say, the list was unfortunately lost by one of my assistants in a Metropolitan Railway-carriage; at all events, enough was said in this and other countries about these bright lines in the years 1869 and 1870 to have given rise, at all events, to the hope that any one interested in solar physics would be perfectly familiar with them. Among other matters which called attention to their existence was a correspondence which took place in the *Comptes Rendus* of the Academy of Sciences in Paris between Father Secchi and another observer in connexion with solar spots. I have remarked that a large dispersion is requisite to see these bright lines, because with a small dispersion bright regions of another kind in the solar spectrum are very obvious. When this small dispersion, however, is changed for a large one, one sees that these bright regions in the solar spectrum are due to the absence of fine lines; and, indeed, if one observes the solar spectrum with considerable dispersion through a cloud which prevents the fine lines from being seen, then there is a very considerable relative diminution in the intensity of some parts of the spectrum, and a very considerable relative increase in others, where these very fine lines are present and absent relatively, so as to give rise to the appearance of a very considerable change indeed in the background of the spectrum.

When, however, a very considerable dispersion is employed and photography is brought into play, if precautions be taken to give sufficient exposure, these bright regions, as opposed to the bright lines, entirely disappear. I have here, by the kindness of two friends, Mr. Rutherford and Captain Abney, the means of showing you exactly what I mean. A Rutherford grating containing 17,000 lines to the inch has been used as a means of obtaining the spectrum; and the film

employed was kindly put on the plate for me by Captain Abney himself. We find, now, that Mr. Rutherford has given us an engine of such enormous power that the fineness of the collodion film is entirely distanced; that is to say, we can get from these perfect gratings spectra so extremely fine and so full of detail, that they can be enlarged until the structure of the ordinary collodion comes in and prevents a fine picture. But if instead of the ordinary collodion process, those which are being worked out with such success by Captain Abney be employed, then it appears that the film is as perfect a thing in its way as the grating is in its way, and one can go on obtaining any magnification one wants.

This is a photograph of the H lines obtained by the grating and film to which I have referred. Between the H and K lines, where the eye sees faintly three lines, there are now nearly a hundred; and that will speak more than any words of mine as to the extreme importance of the introduction of photography in such a research as this. Now here there are no bright lines; but, very conveniently, this next photograph contains one of the bright lines discovered and carefully recorded by Cornu, who has recorded bright lines in the ordinary solar spectrum as well as Hennessy. In exactly the middle of the field now is the bright line recorded as a bright line by Cornu in his map of the blue end of the solar spectrum; but excepting that one bright line, which is much more intense than any other part of the spectrum, bright lines are non-existent.

During the course of last year Dr. Draper, of New York, published the first results of a research which he has undertaken, going over very much the same ground with regard to the metalloids as had been gone over in this country with regard to the metals. Dr. Draper, who has long been known as a most earnest student of science, approached this subject with a wealth of instrumental means almost beyond precedent; and his well-known skill and assiduity, in the course of the two or three years during which his work was carried on, enabled him to accumulate facts of the very greatest importance. I am most anxious to make these preliminary remarks, and to state my very highest respect for Dr. Draper, because in referring to his work I shall have to point out that some of his results are, in my opinion, not yet completely established. Dr. Draper,

in the first instance, claims the discovery of the bright lines already referred to, and bases a new theory upon them. It is by no means as a stickler for priority that I regard this as a very great pity, but because I think that, if the very considerable literature touching these bright lines (papers by Young, Cornu, Hennessy, Secchi, and others) had been before Dr. Draper when his paper was written, the necessity for the establishment of a new theory of the solar spectrum, which doubtless cost him very considerable thought, would probably have been less obvious.

Dr. Draper was so kind as to send me some little time ago a photograph of the solar spectrum confronted with the lines of oxygen ; and the result which this photograph is claimed to show is, that a considerable number of the oxygen-lines are coincident with bright lines in the solar spectrum. I will throw this photograph of Dr. Draper's on the screen, in order that we may have common ground of thought. The lower part of the photograph gives the lines of oxygen ; the middle part gives Dr. Draper's photograph of the sun, and the upper part a photograph of the sun taken in England, which I have put side by side with Dr. Draper's in order that the definition of the two photographs may be contrasted.

On examining the upper photograph with a very considerable magnifying-power, the detail comes out marvellously, and the spectrum between the more marked lines is found to be occupied with extremely fine lines in those regions where Dr. Draper's photograph gives ribbed structure, which, I fear, may not be due to the solar spectrum at all. In the silver-on-glass gratings, one of which Mr. Rutherford was so kind as to give me, I find that, in consequence of the grating being ruled on the back surface of the glass and the double transmission of the light through the plate, there is a considerable formation of Talbot bands, and the solar spectrum is in some regions entirely hidden and absolutely transformed. Lines are made to disappear ; lines are apparently produced ; so that if one compares a part of the spectrum taken with one of these silver-on-glass gratings with an ordinary refraction-spectrum, the greatest precaution is requisite. Indeed I think I am not going beyond the mark when I say that the positions of all lines below the third or fourth order of inten-

sity must be received with very great caution indeed when these gratings are employed. So well is this known to Mr. Rutherford himself, who prepared these gratings for another purpose, that he is now, with equal generosity, distributing gratings containing the same number of lines to the inch (17,300, or something like that) engraved on speculum-metal in order that these defects may be obviated.

With regard to this work of Dr. Draper's, then, I wish to point out that the photograph in which these comparisons with the oxygen-lines have been made is not one which is competent to settle such an extremely important question. Secondly, upon examining these oxygen-lines, I do not find the coincidences to which he refers with bright solar lines and oxygen-lines in that part of the spectrum with which I am most familiar, for the reason that there are no bright lines whatever in this portion of the spectrum. I have here enlargements of negatives going nearly the whole length from G to H, one of the regions which are included in this photograph of Dr. Draper's. I have carefully gone over these regions line for line; and in no case do I see any bright line in the sun whatever coincident with any line of oxygen whatever. I cannot profess to have gone over the ground in the ultra violet; but it will appear to me very surprising indeed if, when we go further, when we include the H and K lines which have already been thrown on the screen, that Dr. Draper will find any possible coincidences with bright lines of the sun even there, because, when perfect instrumental conditions are brought into play, no bright line whatever exists in the part of the solar spectrum which is included in this map.

The bright line discovered by Cornu exists outside K; but between the region included in this map and the G lines I find no obvious bright line.

There is an experiment which any member of the Physical Society who possesses a spectroscope with three or four prisms can make for himself. Take the spark in air in an apparatus of the kind to which I have referred, use a comparison prism, flood the air with nitrogen, and in the field of view which includes *b* (and therefore one of the most marked bright lines in the solar spectrum itself) you will find three or four undoubted lines of oxygen. I have made that experiment, which

is quite a simple one ; and I find no coincidences in this part of the spectrum between any of these oxygen-lines and the undoubted bright lines. I have not tried it yet for the lower parts of the spectrum in the red and yellow, because I hope that Dr. Draper will try for himself.

I do not say that Dr. Draper's alleged discovery is no discovery at all ; I say (and I think it is my duty to say it, as I have been occupied in closely allied work for some considerable time) that I do not hold it to be established.

I have no doubt that Dr. Draper will carefully go over his work himself; and I am quite certain that he will be the very first to hail what I have said today with satisfaction, because his desire, I am sure, is the desire of every true man of science, that the truth should prevail. In any case Dr. Draper has begun work in a branch of the chemical inquiry into solar matters which, up to the present time, has been sadly neglected ; and we should all be grateful to him on that ground. I have no doubt that he on his side, as I on mine, hopes, as I said before, that the Physical Society of London and the Physical Societies of America will come forward and supply more workers for a branch of science which I am certain in the future will be regarded as one of very considerable importance.

XXXIII. *On the Discharge of Water from Orifices at different Temperatures.* By Professor W. C. UNWIN, M.I.C.E.

IN the Journal of the Franklin Institute for May 1878, there is a paper by Chief-Engineer Isherwood, of the U.S. Navy, giving an account of some experiments on the discharge of water from orifices at different temperatures. Those experiments appear to have been made on a sufficient scale and with very great care ; and they lead to the conclusion that temperature has a very marked influence on the discharge. The author evidently supposes his conclusions to be applicable to orifices in general ; for he remarks that, "in the various determinations which have been made of the ratio of the actual to the theoretical discharge of water through orifices, the temperature of the water should have been noted. The experi-

mental ratios are true for only the experimental temperatures, and need reduction to a standard temperature."

The experiments were made by noting the time in which the level of the water in a cylindrical vessel fell from one level to another, the water being discharged from a given orifice. The observed results of the experiments are not given. These results were plotted in a diagram, and a fair curve drawn passing as evenly as possible through the plotted points. The results are stated to have been corrected for the dilatation of the orifice by heat; but it is not stated whether any correction was made for the dilatation of the volume of the vessel from which the water flowed, a correction quite as important as the other. The following short Table gives a few of Mr. Isherwood's results, as measured by him from the curve representing the observed results:—

Temperature, Fahrenheit. °	Relative time of discharge for equal volumes.	Relative velocities of discharge for equal volumes.
32	1·0000	1·0000
60	0·9896	1·0105
100	0·9696	1·0313
140	0·9457	1·0577
180	0·9156	1·0922
212	0·8855	1·1293

Thus the velocity of discharge increases 12 per cent. as the temperature rises from 32° to 212°, and it increases 8 per cent. as the temperature rises from 60° to 180°.

Now there is this difficulty in accepting the results of Mr. Isherwood's experiments,—that the actual velocity of discharge at ordinary temperatures differs from the whole velocity due to the head by only from 3 to 6 per cent. for simple orifices. It is not easy to see that any increase of fluidity of the water or diminution of friction could do more than annul this loss of from 3 to 6 per cent. Mr. Isherwood's experiments seem to imply that the velocity of discharge at high temperatures may be greater than the velocity due to the head. It seemed worth while therefore to repeat the experiment. The means at the author's disposal did not permit him to make the experiments on quite so large a scale as those of Mr. Isherwood; but it

was, he believes, quite large enough to indicate any gain of velocity of the amount mentioned above.

A cast-iron cistern was used, the interior bored out to a diameter of 0·4 metre. The first orifice tried was a carefully formed brass conoidal orifice, formed as nearly as might be to the shape of the vena contracta, and very approximately 0·01 metre diameter. Three pointed indexes were fixed in the cistern, below the surface of the water; so that, as the level of the water descended, the instant at which the point broke the surface could be very exactly observed. Calling the levels of the three indexes A, B, and C, the time was noted in which the water-level descended from A to B and from A to C. A chronograph-watch was used, the seconds' hand being started at the moment the water-level was at A. When the level reached B, the time elapsed was noted by an observer counting seconds. When the level reached C the hand of the watch was stopped. This last observation was perhaps more reliable than the intermediate one at the level B.

For the higher temperatures the water was taken from a steam-engine boiler; it was somewhat discoloured by iron and sediment. The same water was used in the experiments at lower temperatures, but in its ordinary clean condition. The author does not think that the condition of the water made any sensible difference in the results of the experiments.

Experiments on a Conoidal Orifice, June 4, 1878.

Temperature, Fahrenheit.	Time of fall of water-level in seconds.	
	From A to B.	From A to C.
190°	59	89
190	58½	88½
130	59½	90
60	62	93
60	61½	92½
<i>Mean Results.</i>		
190	58·75	88·75
130	59·5	90·00
60	61·75	92·50

These results show a distinct increase of velocity of discharge at the higher temperatures; but the increase from 60°

to 190° is only 4 per cent., or less than half the increase observed by Mr. Isherwood.

When water issues from an orifice with gradually diminishing head, the relation between the time and volume of discharge is given by the well-known equation

$$t = \frac{\Omega}{c\omega} \left\{ \sqrt{\frac{2h_1}{g}} - \sqrt{\frac{2h_2}{g}} \right\}, \quad . \quad . \quad . \quad . \quad (1)$$

where Ω = area of water-surface in reservoir,

ω = area of orifice,

h_1, h_2 = heads at beginning and end of experiment above centre of orifice,

t = time of outflow in seconds,

c = coefficient of discharge.

Let D = diameter of the cylindrical reservoir, and d = diameter of the orifice. Then

$$\frac{\Omega}{\omega} = \frac{D^2}{d^2}.$$

Hence the equation above becomes

$$t = \frac{D^2}{cd^2} \sqrt{\frac{2}{g}} \{ \sqrt{h_1} - \sqrt{h_2} \}.$$

In these experiments $D = 15.7$ inches, $d = 0.3937$ inch. Reducing these values to feet and introducing them in the equation,

$$t = \frac{394.376}{c} \{ \sqrt{h_1} - \sqrt{h_2} \}.$$

The heights of the index-points above the centre of the orifice were, as nearly as could be measured,

A		1.467 foot.
B		1.133 "
C		0.9775 "

Hence, for experiments in which the level fell from A to B,

$$c = \frac{57.895}{t}; \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and for experiments in which the level fell from A to C,

$$c = \frac{87.748}{t}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Neglecting for the present the expansion of the reservoir and orifice, the coefficients of discharge deduced from the experiments are as follows:—

Coefficients of Discharge.

		Fall of level from A to B.	Fall of level from A to C.
190°	. . .	{ .9813	{ .9859
		{ .9896	{ .9915
130°	. . .	.9730	.9750
60°	. . .	{ .9338	{ .9435
		{ .9414	{ .9486

Mean Values of c.

190°		0.9871
130°		0.9740
60°		0.9418

The experiments on a conoidal orifice having shown a small but definite influence of temperature on the discharge, it seemed desirable to try whether a similar effect would be produced in the case of a thin-edged orifice. With the conoidal orifice there is no contraction of the jet, and the discharge is less than the so-called theoretical discharge by an amount depending only on the friction of the orifice. In the case of a thin-edged orifice, the jet contracts to an area of about $\frac{5}{8}$ that of the orifice; and the discharge is diminished not only by the friction, but also to a much greater extent by the contraction. The thin-edged orifice was 1 centimetre diameter; and the heads were nearly the same as before.

*Experiments on Thin-edged Orifice, 1 centim. in diameter,
June 12, 1878.*

Temperature, Fahrenheit.	Time of discharge of water between A and B in fifths of a second.	Time of discharge of water between A and C in fifths of a second.
205°	503	748
205	500	747
140	507	744
65	500	746
61	495	740
61	495	740

Mean Values.

62°	496.6	742
140	507.0	744
205	501.5	747.5

The times here recorded show that, in the case of a thin-edged orifice, the temperature has an extremely small influence on the discharge, and that, unless the small differences in the experiments are errors of observation, the discharge is greater at low temperatures. Whether this is due to the increase of temperature increasing the contraction at the same time as it diminishes the friction, could only be determined by much more extensive experiments.

For these experiments, when the level fell from A to B,

$$c = \frac{292.75}{t}; \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and when the level fell from A to C,

$$c = \frac{443.71}{t}, \quad . \quad . \quad . \quad . \quad . \quad (5)$$

t being in fifths of a second.

Coefficients of Discharge for Thin-edged Orifice.

Temperature, Fahrenheit.	Values of c .	
	Fall of level from A to B.	Fall of level from A to C.
20 $\frac{5}{8}$	.5820	.5932
205	.5855	.5940
140	.5774	.5964
65	.5855	.5948
61	.5914	.5996
61	.5914	.5996
<i>Mean Values.</i>		
20 $\frac{5}{8}$	.5837	.5936
140	.5774	.5964
62	.5894	.5980

These results seem to show that the temperature has hardly any sensible influence on the discharge from orifices of this kind.

It will be seen that the results of these experiments do not at all agree with those of Mr. Isherwood; and although made on a smaller scale, the author believes that if the influence of temperature had been nearly as great as that stated by Mr. Isherwood, it could not possibly have escaped detection. Minute errors in measuring the head or the size of the orifice would sensibly affect the values of the coefficients obtained; and

these may possibly be wrong to the extent of 2 or 3 per cent.; but these errors would not affect the relative values of the coefficients in any sensible degree, and the author therefore believes that temperature has a far less influence on the discharge from simple orifices than Mr. Isherwood's results would imply. It is difficult to explain to what the higher results obtained by Mr. Isherwood are due; but the conjecture may be hazarded that the orifice in his experiments was very exceptionally placed. It was at the end of a bell-mouthed tube some 10 inches long, a great part of which was only $\frac{3}{4}$ inch diameter; and there was a plug-cock immediately above the orifice. It seems possible that there was a good deal of friction in this pipe, and that the diminution of friction in this part of the apparatus led to the increase of discharge as the temperature increased*.

Thus far the effect of the temperature on the capacity of the reservoir and the size of the orifice has been neglected. It only remains to examine whether the expansion of these has any material influence on the results.

The effect of temperature on the quantities entering into the equation of flow is twofold. First, the ratio $\frac{D^2}{d^2}$ is altered, because the mouthpiece was of brass and the reservoir of cast iron; and the former expands more than the latter. Secondly, the level marks being attached to the side of the cistern, the distance between these marks and the centre of the orifice increases as the temperature rises. There is, however, an uncertainty in applying a correction for the expansion of the metal, because, its external surface being exposed to the air, its mean temperature would be less than the temperature of

* It is impossible to calculate, except roughly, the frictional resistance of the tube to which, in Mr. Isherwood's experiments, the orifices were attached. Taking 4 inches length of pipe $\frac{3}{4}$ inch in diameter, and neglecting the bell-mouthed part, we get, using D'Arcy's coefficient of friction, and putting the data in feet:—

For a discharge of	0.0167	.....	0.0374
„ velocity	5.5	.....	12.2
„ head lost in pipe	0.6	.....	0.12
„ total head	5.0	.....	1.0

So that apparently about 12 per cent. of the head may have been lost in the friction of the pipe leading to the orifice.

the water. The following estimate of the correction is therefore approximate only.

Let e_b be the expansion of brass per unit of length and per degree;

e_c the expansion of cast iron estimated in the same way;

τ = the excess of temperature during the experiment reckoned from 60° .

Then, in consequence of the expansion of the metal, the ratio of the areas $\frac{D^2}{d^2}$ becomes

$$\frac{(1 + e_c \tau)^2 D^2}{(1 + e_b \tau)^2 d^2},$$

and the true difference of the square roots of the heads is

$$\sqrt{1 + e_c \tau} (\sqrt{h_1} - \sqrt{h_2}).$$

The formula of flow, allowing for the alteration of the dimensions by rise of temperature, is therefore

$$t = \frac{(1 + e_c \tau)^2}{(1 + e_b \tau)^2} \sqrt{1 + e_c \tau} \frac{D^2}{cd^2} \{ \sqrt{h_1} - \sqrt{h_2} \}.$$

Let $e_c = .000006$,

$e_b = .00001$,

$\tau = 190^\circ - 60^\circ = 130$;

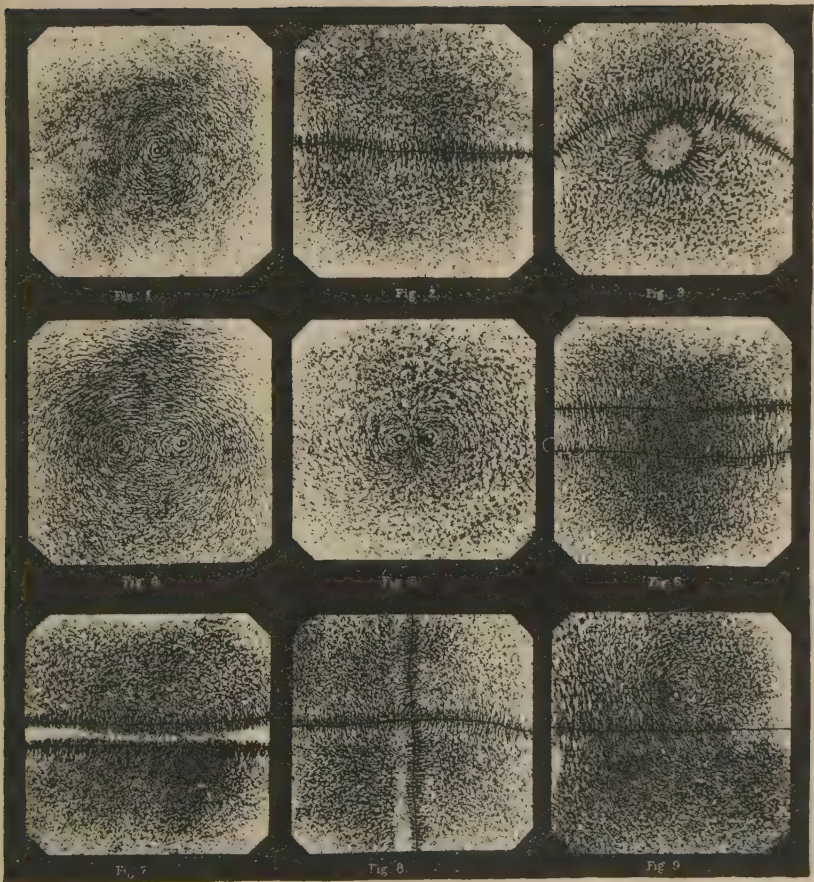
$$\frac{(1 + e_c \tau)^2}{(1 + e_b \tau)^2} \sqrt{1 + e_c \tau} = \left(\frac{1.00078}{1.0013} \right)^2 \sqrt{1.00078} = 0.999355.$$

Hence it is obvious that the effect of the expansion of the reservoir and orifice is very small for the range of temperature in these experiments. Allowing for that expansion, we get for the experiments at 190° ,

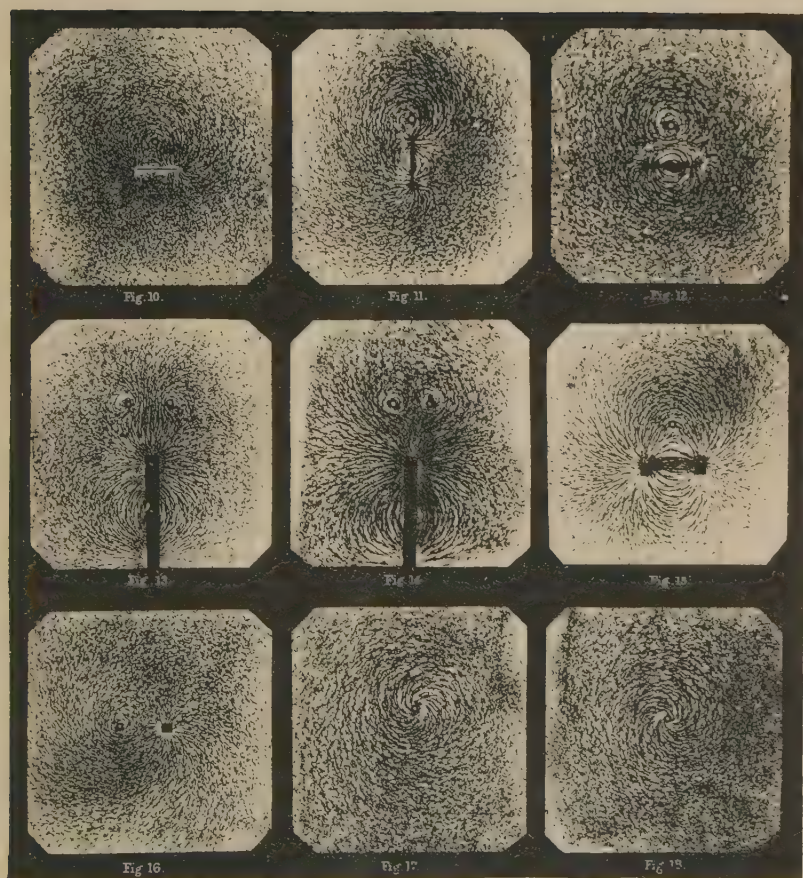
$$c = \frac{.99935 D^2}{td^2} \{ \sqrt{h_1} - \sqrt{h_2} \},$$

or slightly smaller values of the coefficient than those given above.

It is rather curious that it is stated in Mr. Isherwood's paper that the results are corrected for the variation of the size of the orifice as the temperature varied, but no mention is made of a correction for the size of the reservoir or the expansion of the vessel to which the index-marks denoting the initial and final heads were attached. If these latter corrections have



MAGNETIC FIGURES
ILLUSTRATING ELECTRO-DYNAMIC RELATIONS.



MAGNETIC FIGURES
ILLUSTRATING ELECTRO-DYNAMIC RELATIONS.



been omitted, though this is difficult to believe, Mr. Isherwood's results should be divided by

$$(1 + e_c \tau)^2 \sqrt{1 + e_c \tau},$$

where e_c is the coefficient of expansion of the material of the reservoir, whatever that was. This would sensibly diminish the apparent increase of discharge at high temperatures given in his experiments.

XXXIV. *Magnetic Figures illustrating Electrodynamical Relations.* By SILVANUS P. THOMPSON, D.Sc., B.A., F.R.A.S., Professor of Experimental Physics in University College, Bristol.

[Plates VIII. and IX.]

IN a preliminary communication to the Physical Society in February of the present year, the author announced a method of studying and illustrating the known laws of the mutual attractions or repulsions of conductors traversed by electric currents. The present paper is a complete statement of the facts obtained in the experimental research which formed the basis of that communication.

While preparing a set of magnetic currents to illustrate the mutual actions of magnet-poles, it occurred to the writer that the mutual attractions and repulsion of currents might be illustrated in a similar manner by the figures formed with iron filings. He was aware* at that time that the lines of force of a straight conductor carrying a current were a series of concentric circles lying in a plane to which the conductor was normal. The series of figures now published originates, therefore, with the discovery of Faraday that the seat of the mutual actions of currents and of magnets must be sought in the surrounding medium. Since the communication of the preliminary notice, the writer has learned that one or two of the figures had been previously and independently observed by Professor

* See Faraday, 'Experimental Researches in Electricity,' vol. iii. p. 400, § 3239, and plate iii. fig. 17; Guthrie, 'Magnetism and Electricity,' p. 254, fig. 225; Clerk-Maxwell, 'Electricity and Magnetism,' vol. ii. art. 477.

F. Guthrie, but not published. Two others, Nos. 4 and 5 of the present series, are imperfectly given by Faraday in figures 18 and 19 of plate iii. in the third volume of his 'Experimental Researches' (Series Twenty-ninth)*, and without reference to the conclusions to be derived from their forms, which Faraday apparently overlooked†.

The method employed for preserving the figures has been uniform throughout the series. Plates of glass, $3\frac{1}{2}$ inches long by $3\frac{1}{4}$ inches broad, were coated with a solution of gum-arabic and gelatine, and were then carefully dried. When the arrangement of magnets or of conducting-wires had been made for the particular case of the experiment, and the plate been laid in a horizontal position, fine filings of wrought iron previously sifted were dusted over the plate through muslin, and the plate was tapped lightly with vertical blows from a piece of thin glass rod. When the filings had arranged themselves, and the plate was still *in situ*, a gentle current of steam was allowed to play upon the plate, condensing upon the surface of the gum and softening it, and thus allowing the filings to embed themselves where they lay. After the gum had again become hard, the prepared face was covered by a protecting plate of glass, on which in certain cases were drawn the positions of the wires or magnets employed. The figures fixed in this manner are suitable for projection with the lantern upon the screen. They can be readily photographed for transparencies, or for paper prints; specimens of each of these methods of photographic reproduction are exhibited to the Society.

Figure 1 represents the condition of the magnetic field surrounding the current in a straight conducting-wire, which was carried vertically through a hole drilled in the plate. The wire employed throughout the series was a silver one of about .8 millim. in diameter. The battery power employed for this

* And 'Phil. Trans. 1852, p. 137.

† The attention of the writer has also been drawn to a statement in the American Journal of Science for 1872, p. 263, by Professor A. M. Mayer, that he has obtained magnetic "spectra" from electric currents in a manner somewhat similar to that now described. The figures have, however, remained unpublished and undescribed, so that the writer has no means of learning how far the substance of the present communication may have been anticipated.

experiment was that of 20 Grove's cells arranged in two series of ten each. In some of the succeeding experiments a less current was found sufficient.

But for the imperfections of the method of experiment, these curves would be perfect circles, and the distances between two successive lines of force would be proportional to the square of the distance from the central point. The equipotential magnetic surfaces, being always normal to the magnetic lines of force, would be represented by a system of radial lines forming equal angles with one another. There appears to be no recognized name for the closed curves traced out by the lines of force around conductors carrying currents. With great diffidence I therefore beg to speak of them as isodynamic lines. They are theoretically disposed about a single straight conductor in a perfectly concentric manner, and at such distances apart as would be defined by the requirement that a parallel conductor, carrying a like current of unit strength, would do unit work in passing from one isodynamic line to the next. The absolute value of an isodynamic line would of course be determined (like magnetic and electrostatic potential) by the work done by a like element of current in passing to any point in that line from an infinite distance. No work is done in moving an element of a parallel current along an isodynamic line, just as no work is done in moving a magnet-pole along in an equipotential surface. The isodynamic lines occupy, therefore, exactly the same relation to the element of the circuit, as do the equipotential surfaces to a magnet-pole or to an electrified point.

Figure 2 represents the field above a horizontal wire carrying a current, and separated from the filings by the thickness of the glass (about 1.7 millim.). The lines cross the wire at right angles, and are really the projections of a series of such circles as exist in figure 1.

Figure 3 exhibits the form assumed by the filings when the wire beneath the plate was coiled into a simple loop, a small piece of mica being inserted to prevent contact where it re-crossed its path. The lines of the field within the loop run longitudinally; and their projections on the surface are mere points, as the filings show.

In figures 4 and 5, two wires pass vertically through the

plane of the figures, carrying parallel currents, which in figure 4 are in the same direction, in figure 5 in opposite directions. Ampère's well-known law of the attraction in the former case, and of the repulsion in the latter, is well illustrated by the forms of the magnetic curves. In the former, where the parallel currents attract, the outer isodynamic lines are closed curves embracing both centres, the inner are distorted ovals about each centre—the whole forming a system of lemniscates, as would necessarily be the case, since the attraction at any point in the plate varies inversely as the square of the distance from each current*.

In figure 5, where the parallel currents repel each other, the lines of force due to either current in no case enter or coalesce with those of the other current. They form two series of ovals of a peculiar form, flattened on the sides presented towards the opposing series.

The conception of Faraday, "that the lines of magnetic force tend to shorten themselves, and that they repel each other when placed side by side," has been shown by Clerk-Maxwell, who thus concisely states it, to be perfectly consistent with the theory that explains electromagnetic force as the result of a state of stress in the medium filling the surrounding space†. Faraday also observes that "unlike magnetic lines, when end on, repel each other, as when similar poles are face to face," and that "like magnetic lines of force," when end on to each other, coalesce. The terms "like" and "unlike," as applied to magnetic lines of force, refer, of course, to the two cases of similarly or oppositely directed lines, the positive direction of a line of force being reckoned as the direction in which a north-seeking pole on it would tend to move‡. The mutual coalescence or repulsion exerted between the lines of force of unlike or like magnetic poles is familiarly employed in the experimental illustration of magnetic phenomena, so well known since the researches of Professor Robison and Dr. Roget on the magnetic curves, and appears to have been recognized long

* See Thomson and Tait, 'Natural Philosophy,' art. 508, vol. i. p. 382.

† Clerk-Maxwell, 'Electricity and Magnetism,' vol. ii. art. 645; Faraday, 'Experimental Researches,' 3266, 3267, 3268.

‡ See Clerk-Maxwell, 'Electricity and Magnetism,' art. 489; L. Cumming, 'Theory of Electricity,' p. 194.

before*. It is believed that the present is the first distinct attempt to apply similar considerations to the illustration of electrodynamic relations between systems of conductors carrying currents, and between conductors of currents and magnet-poles.

The isodynamic lines, which are lines of magnetic force, tend to shorten themselves. A very hasty inspection of fig. 4 will show that if any one of the system of lemniscates were to "shorten itself," it would tend to bring the two centres nearer together. Consider each isodynamic line as a ring of some elastic material (as, for example, an indiarubber ring) stretched around a bundle of smooth wires, the cross section of the bundle having a perimeter corresponding in form to the isodynamic line under consideration. The maximum shortening of such an elastic ring would take place when the enclosed area was made a circle. In other words, the lemniscate-form isodynamics tend to become circles, and the two like parallel currents are mutually urged towards each other.

In figure 5 the shortening of the isodynamic lines, and their approach to the truly circular form, could only be accomplished by the wider separation of the two conductors from each other. Hence the mutual repulsion of two parallel conductors carrying oppositely directed currents.

Figures 6 and 7 show the lines of force above the parallel currents when these pass horizontally below the glass. In the case of like currents the lines coalesce. In the case of unlike currents they repel each other, and pass between the two wires in a direction vertical to the plane of the glass, where their characteristic form, as lines, is lost. The observation that the filings adherent to wires carrying like parallel currents are mutually attractive appears to have been first made by Davy.

Figure 8 illustrates the law of currents crossing one another at a point. In the two quadrants in which the currents both run to or from the central point, the lines of force tend to coalesce. In the alternate quadrants they mutually repel each other; and the angle of these quadrants tends to increase.

In figure 9 one current is carried horizontally below the glass,

* See Musschenbroek, *Dissertatio Physica Experimentalis de Magnete*, cap. iv. exp. cxvii., and tab. iv. figs. 4 & 5.

the other traverses the plane of the figure normally. The dissymmetry of the resultant distribution of the lines reveals the dissymmetrical nature of the force which tends to bring the currents into parallelism. Any shortening of the isodynamic lines would tend to move the vertical current from that quadrant over which the lines are unbroken. Figures have also been obtained with two currents crossing the plate in a vertical plane of incidence, but each at 45° to the normal. With some distortion, these figures bear a general resemblance to figs. 4 and 5 in the two cases of the currents passing through the plate in similar or in opposed directions. In the former case their angular separation tends to diminish, in the latter to increase.

Figures 10, 11, and 12 introduce the action of a vertical current upon a small magnetic needle lying on the glass plate. In the first case the needle lies in stable equilibrium almost tangentially to the isodynamic lines; in the third its position is reversed and unstable; in the second case it is set at right angles to the directive action of the current. The dissymmetrical action of the forces on its poles produces a couple tending to turn it about its centre, as would be inferred from an inspection of the lines of force of the figure.

Figures 13 and 14 illustrate a deduction from the theory of the magnetic shell. A conductor carrying a current is acted upon by a force urging it forward so as to make the number of like lines of force included within it a maximum*; that is to say, a north-seeking pole is attracted into a circuit on the side from which the positive current appears to circulate in a right-handed cyclical order (or in the same direction as the hands of a clock). Similarly the circuit is urged backwards from a contrary pole, and tends to make the number of unlike lines of force included within it a minimum. In the figures a current ascends through the plane of the figure on the left, and descends through it on the right, in a right-handed cyclical order as seen from the magnet. Hence a north-seeking pole is attracted, and a south-seeking pole repelled.

Figure 15 results from the action of two magnet-poles upon a vertical conductor, which in this case is attracted between the poles.

* Clerk-Maxwell, 'Electricity and Magnetism,' art. 490.

Figure 16 illustrates the mutual tendency to rotation between a magnet-pole and a conductor carrying a current parallel to the axis of the magnet. In the figure, where the vertical current passes upwards through the glass, the neighbouring south-seeking pole (marked in position by a square dot) is urged round the current with a couple tending in a right-handed cyclical rotation. The couple is reversed, and acts in a left-handed order, if either the current or the magnet-pole be reversed. The contrasted dissymmetry so produced is very curious, and the mutual displacement of the radial lines of force of the pole and of the circular lines of the current is very significant.

Figures 17 and 18 show lines of force arranged spirally in the field. In these a current passes upwards through the glass, while the pole of a magnet is placed vertically beneath: the current, in fact, passes through the magnet. The form of the lines of force is remarkable. No work would be done on or by an element of a vertical current in bringing it up to the centre along one of the spiral lines; for the work done *by* it in bringing it in the spiral path across the successive circular isodynamic lines of the current would be equal to that done *upon* it in carrying it across the successive radial lines of force of the magnet-pole. The equipotential surfaces of this field are consequently another series of spirals of an opposite cyclical order. In figure 17 the current running up through a south-seeking pole produced a right-handed spiral; in figure 18, with a north-seeking pole the spiral is of the opposite order. Since the magnetic potential decreases from a magnet-pole with the inverse square of the distance, and since the inductive action of the current on a point in the plane of the figure also decreases according to the inverse square of the distance from the current, each branch of the spirals would be described by a moving point whose angular displacement from the arbitrary zero is simply proportional to the distance from the central point. The results of actual measurement of the spirals at successive distances of whole millimetres from the centre show as near an agreement with this supposition as the roughness of the method of procuring the curves permits. The number of branches of the spiral will clearly be proportional to the strength of the magnet pole. The obvious result of a "short-

ening" of the spiral lines would be to produce a rotational movement, such as we know to be produced on a free-magnet pole under the influence of a current traversing it longitudinally.

I am indebted to Mr. Robert Gillo, of Bridgwater, for the admirable photographic copies of the various figures.

June 19, 1878.

XXXV. *On the Light reflected by Potassium Permanganate.*

By Sir JOHN CONROY, *Bart., M.A.*

THE light reflected from the surface of potassium permanganate was originally examined by Haidinger, who announced (*Sitzungsberichte der kaiserlichen Akademie der Wissenschaften*, Band viii. 1852, p. 133), that when the light reflected from the surface of the crystals and of the substance rubbed on a plate of glass was examined with a dichroscopic lens, the portion polarized in the plane of incidence was light yellow at low angles, and became white as the angle increased, whilst the portion polarized perpendicularly was light yellow, and became green and blue as the angle increased.

Professor Stokes found (*Phil. Mag.* vi. 1853, p. 400) that the reflected light contained four bright bands, corresponding in position to the dark bands of the absorption spectrum of a solution of the substance, and that when the reflected light was separated into two streams polarized in, and perpendicular to, the plane of incidence, and then examined by a prism, the bands were hardly visible in the one, and the other at a certain angle consisted mainly of them.

E. Wiedemann has recently published (*Pogg. Ann.* cli. 1874, p. 625) an account of some experiments he has made on the same subject. He found that whilst the dark bands of the reflection spectrum did not even partially cover those of the absorption spectrum, they did not lie exactly intermediate between any two of them—and, further, that the position of the bands was independent of the angle of incidence, both with ordinary light, and with that polarized in the plane of incidence; but with light polarized perpendicularly to this plane, the bands occupied the same position up to a certain angle,

and then with a slight increase of the angle suffered sudden displacement towards the blue, and a new band appeared near D. He also found that with light polarized perpendicularly to the plane of incidence, the position of the bands was independent of the nature of the surrounding medium, being the same when the permanganate was in air, benzene, and bisulphide of carbon; but when the light was polarized in the plane of incidence, with the increase of the refractive index of the medium the bands were more and more displaced towards the blue.

For some experiments I have made on the same subject I have used a Babinet's goniometer, which has, in addition to the ordinary horizontal stage, a vertical one so arranged that the reflecting surface can be placed over the axis of the instrument. Sunlight was used, which could be polarized in any plane by a Nicol supported by the fixed arm of the goniometer; and a small direct-vision spectroscope, by Hilger, with a "bright-point" micrometer and a reflecting prism for bringing a second spectrum into the field, was carried by the other arm of the goniometer. By placing a beaker on the horizontal stage, and, after the surface of the permanganate had been properly adjusted, filling it with the liquid and limiting the incident beam by a narrow vertical slit, the light reflected from the surface of the substance when immersed in a liquid could be examined.

The experiments were usually made with potassium permanganate crushed, and burnished with an agate on a piece of finely-ground glass; and it was found that the light reflected from the surface of crystals and from that of the substance rubbed on glass was identical; except that the blue rays were more intense in the light reflected by the crystals, and the higher bands were more distinctly seen.

The surface-colour of potassium permanganate, and the position and intensity of the bands in the spectrum of the reflected light, are independent of the relative position of the plane of incidence to the long axis of the crystal, or to the striæ produced by rubbing, when the powdered substance burnished on glass is used.

1. *Surface-Colours*.—Freshly prepared surfaces of potassium permanganate appear of a pale yellow when light, either unpolarized or polarized in any plane, is incident upon them

at low angles. But with ordinary light, and with light polarized in the plane of incidence, the amount of white light reflected is so great at high angles that the surface-colour, if any, is completely masked.

When the incident light is polarized perpendicularly to the plane of incidence, or when unpolarized light falls on the surface and a Nicol is placed between the eye and the permanganate, with its principal section in the plane of incidence, the surface-colour is seen to change as the angle increases, becoming successively green and blue, and finally white and metallic.

The surface-colours alter with the surrounding medium. The following Table gives, approximately, the colour at various incidences, (A) when the light is either unpolarized or polarized in the plane of incidence, and (B) when it is polarized perpendicularly to that plane, for potassium permanganate in air, tetrachloride and bisulphide of carbon.

Angle of incidence.	Surrounding medium.		
	Air.	Tetrachloride of carbon.	Bisulphide of carbon.
30. {	A Pale yellow.	Yellow-green.	Yellow-green.
	B " "	" "	Green.
35. {	A Pale yellow.	Yellow-green.	Yellow-green.
	B " "	" "	Green.
40. {	A Pale yellow.	Yellow-green.	Yellow-green.
	B " "	Green.	Green.
45. {	A Pale yellow.	Yellow-green.	Yellow-green.
	B " "	Green.	Blue-green.
50. {	A White.	Yellow-green.	Yellow-green.
	B Pale yellow.	Bright green.	Blue-green.
55. {	A White.	Green.	Yellow-green.
	B Yellow, with a green tinge.	Blue-green.	Blue-green.
60. {	A White.	Green.	Green.
	B Brilliant green.	Blue-green.	Blue-green.
65. {	A White.	Green.	Green.
	B Blue-green.	Blue-green.	Blue-green.
70. {	A White.	Greenish.	Greenish white.
	B Blue.	" "	" "
75. {	A White.	" "	" "
	B Metallic, with blue shade.	" "	" "

2. *Reflection Spectra.*—With unpolarized light, and still more with light polarized in the plane of incidence, the dark bands in the spectrum of the reflected light are never very distinct. I was not able to observe whether the bands shifted or not as the angle of incidence increased, as the amount of white

light reflected at angles of 55° and upwards was so great as to render the bands invisible. They appeared, however, as long as they were visible, to coincide exactly with the bright spaces in the absorption spectrum of a dilute solution of potassium permanganate, which was thrown into the field by means of the reflecting prism.

When the incident light is polarized perpendicularly to the plane of incidence, the dark bands are far more distinctly seen. At angles of less than 40° there are four bands, and the blue end of the spectrum is very weak. As the angle of incidence increases, the intensity of the blue rays diminishes; and then the amount of light in the red decreases; and at about 55° nearly the whole of the light comes from the bright bands.

As the angle of incidence increases beyond this amount, the dark bands gradually move towards the blue end of the spectrum; and at about 60° a new band appears near D. With any further increase of the angle more of the blue rays are reflected; and the bands fade away, those in the more refrangible part of the spectrum disappearing first. The relative intensity of the dark band varies with the angle of incidence. When this is small, the third and fourth bands, counting from the red end, are darkest; with the increase of the angle the second, the first, and finally the new band, become successively darkest.

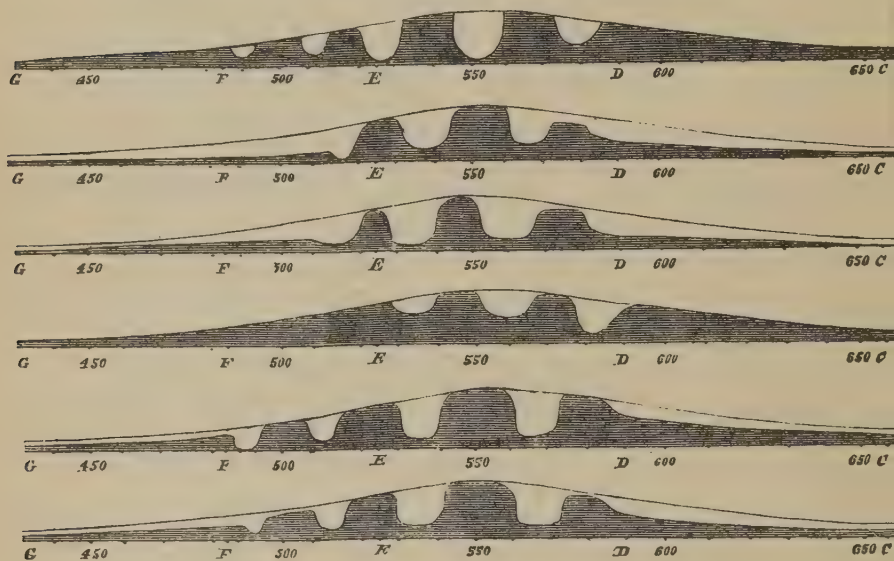
I have not been able to obtain any satisfactory measurements of the amount of the displacement of the bands, as, when a spectroscope of sufficient power to render it an easily measurable quantity is used, the bands become so ill-defined that it is impossible to measure them. Approximately the displacement amounts to about 60° in "tenth-metres;" and the bands tend to coincide with the dark bands of the absorption spectrum, instead of with the bright bands as they do when the angle of incidence is about 55° or less.

The shaded portions of the diagrams are intended to give the relative amount of light, as determined by eye estimations, in the different portions of the absorption and reflection spectra of potassium permanganate—the ordinates being taken to represent the intensity, and the abscissæ wave-lengths. The curved line gives the intensity of the light in the different portions of the normal spectrum, as determined by Mossotti* from Fraunhofer's measurements, neglecting the minor irregularities in the curve as given by him.

* Pogg. *Ann.* lxxii. p. 509.

Fig. 1 is the absorption spectrum of a solution of potassium permanganate in water.

Figs. 2, 3, and 4 the reflection spectra, when the incident light is polarized perpendicularly to the plane of incidence, and falls on the surface at angles of 50° , 60° , and 70° .



As has already been announced by Wiedemann, the position of the bands in the reflected light depends on the nature of the surrounding medium. From the experiments I have made, it appears that, with unpolarized light, the first dark band of the reflection spectrum corresponds in position with the first bright band of the absorption spectrum, whether the permanganate is in air, benzene, or either bisulphide or tetrachloride of carbon; these liquids, however, act on the permanganate, and after a short time the surface becomes altered, and then the bands correspond with the dark bands of the absorption spectrum.

Figs. 4 and 5 represent the distribution of light in the spectrum, with fresh surfaces of potassium permanganate in bisulphide and tetrachloride of carbon, when unpolarized light is incident upon them at an angle of about 55° : in both cases the bands are wider apart than in air.

INDEX.

A.

Page

Abbay, Rev. R., on remarkable atmospheric phenomena in Ceylon . .	80
Absorption, selective	110
— spectrum of potassium permanganate	344
Ackroyd, W., on selective absorption	110
Air, influence of temperature on the passage of, through capillary tubes	246
—, the polarization of electrodes in water free from	15
Albumen in aqueous solution	98
Ammonium and potassium, mixed chlorides of, as cryohydrates and cryogens	6
— and sodium, mixed sulphates of, as cryohydrates and cryogens .	9
— chloride and sulphate of potassium as a cryohydrate	13
— —, anhydrous, separation of, from its solutions	60
— nitrate, separation of, from its solutions	64
—, nitrates of silver and, separation of ice from solutions of . . .	75
— sulphate, anhydrous, separation of, from its solutions	64
— sulphate and nitrate, separation of ice from solutions of	76
Anhydrous salt, separation of, from salt solutions below 0° C. . . .	53
Apparatus to illustrate the interference of two plane waves	182
Aqueous solution, colloids in	95
— —, organic crystalloids in	92
Atmospheric phenomena, remarkable, in Ceylon	80
Ayrton, Prof. W. E., on the electrical properties of bees'-wax and lead chloride	297
—, —, and Perry, Prof. J., on ice as an electrolyte	171, 199

B.

Barium and strontium, mixed chlorides and mixed nitrates of, as cryohydrates and cryogens	8
— chloride, separation of ice &c. from solution of	87
— hydrate as cryohydrate and cryogen	271
— nitrate, separation of ice &c. from solutions of	90
Barometer, mercury, a sensitive	140
Battery, Grove's gas	212
— resistance, a method of measuring	145
— — : conditions for sensitiveness	152

	Page
Battery resistance: measurements in general	145
— — —: practical details	153
—, variation of the electromotive force of a	148
Bees'-wax, electrical properties of	297
Blaikley, D. J., on brass wind instruments as resonators	261
Brass wind instruments as resonators	261

C.

Calcium chloride as a cryogen	1, 3
— — — hydrate, separation of, from its solutions	61
— — —, cryohydrate of	4
— hydrate as cryohydrate and cryogen	272
— nitrate, separation of ice &c. from solutions of	90
Cane-sugar in aqueous solution	92
Capillary tubes, passage of air through	246
Ceylon, remarkable atmospheric phenomena in	80
Chemistry, solar, researches in	308
Chromatic aberration of the eye	157
— — —, bearing of, upon the perception of distance	163
— — —: experimental results and deductions	164
— value of other media than water	287
Circular sector, electrical resistance of a	40
Citric acid as cryohydrate and cryogen	278
Colloids, general remarks on	99
— in aqueous solution	95
—, organic, mixtures of	99
Colour, relation of, to density	115
Colours, surface, of potassium permanganate	341
Conduction, thermal, through a cylinder inserted between metal rods	203
Conroy, Sir J., on the light reflected by potassium permanganate ..	340
Convection, electrolytic	20
Cryogens, a few special	1
—, mixed salts as	4
Cryohydrate, separation of, from salt solutions	87
Cryohydrates, a few special	1
—, mixed salts as	4
Crystalline solids, separation of water from, in currents of dry air ..	281
Crystalloids, organic, in aqueous solution	92
Crystals and other rare substances, absolute thermal conductivity of	201
Currents, thermoelectric, in wires subjected to mechanical strain ..	236
Curves of temperature	207

D.

Daniell cell, form of, convenient as a standard of electromotive force	195
--	-----

	Page
Daniell cell with high internal resistance	196
Density, relation of colour to	115
Detector, the telephone as a	226
Distance, bearing of chromatic aberration upon the perception of ..	163
—, data for the perception of	158

E.

Electric sparks, some phenomena of induced	102
Electrical images, application of, to bounded plates	29
— in rectilinear boundaries	26
— machine, a small	83
— potential in a wedge	41
— properties of bees'-wax and lead chloride	297
— resistance expression for two poles	42
— —: manner in which the image-method fails	49
— — of a circular sector	40
— — of a general isosceles triangle	49
— — of a strip	38
— — of a wedge	35
— — of an equilateral triangle	46
— — of an isosceles right-angled triangle	43
— — of rectilinear figures	30
— — of squares and right-angled triangles	51
Electricity, some problems connected with the flow of, in a plane ..	24
—, the telephone as a source of	224
Electrodes, the polarization of, in water free from air	15
Electrodynamic relations, magnetic figures illustrating	333
Electrolyte, ice as an	171, 199
Electrolytic convection	20
Electrometer, double-wire galvanometer as an	154
Electromotive force, cell for a standard of	197
— —, elimination of variations in	155
— — of a battery, variation of the	148
— —: measurement of any liquid resistances	155
— —, standard of, form of Daniell cell convenient as a	195
Equilateral triangle, electrical resistance of an	46
Eye, chromatic aberration of the	157

F.

Figures, magnetic, illustrating electrodynamic relations	333
Films, Plateau's permanent	209
Fleming, J. A., on the polarization of electrodes in water free from air	15
Foster, Prof. G. C., on the polarization of heat	143
Fuller, G., on a small electrical machine	83

G.	Page
Galvanometer, double-wire, as an electrometer	154
Gelatine in aqueous solution	99
Glycerine in aqueous solution	93
Grove's gas-battery	212
Gum arabic in aqueous solution	97
Guthrie, Prof. F., on a sensitive mercury barometer	140
—, —, on salt solutions and attached water	1, 53, 87, 271
—, —, on the influence of temperature on the passage of air through capillary tubes	246

H.

Heat, polarization of	143
Hughes, Prof., on the physical action of the microphone	255
Hydrate, separation of, from salt solutions, below 0° C.	53, 87
Hydrochloric acid, separation of ice from a solution of	62
Hydrogen and sodium tribasic phosphate, separation of ice &c. from solutions of	88

I.

Ice as an electrolyte	171, 199
—, separation of, from salt solutions below 0° C.	53, 87
—, specific inductive capacity of	180
Images, electrical, application of, to bounded plates	29
—, —, in rectilinear boundaries	26
Interference fringes within the Nicol prism	185
— —, cause of	188
— —: general description	186
Iris, red-orange and blue	192
Iron protosulphate, separation of ice &c. from solutions of	88
Isosceles triangles, electrical resistance of	43, 49

L.

Lead acetate as cryohydrate and cryogen	274
— chloride, electrical properties of	297
— nitrate, separation of ice &c. from solutions of	90
Light reflected by potassium permanganate	340
Lockyer, J. N., recent researches in solar chemistry	308
Lodge, O. J., on some problems connected with the flow of elec- tricity in a plane	24
—, —, on a form of Daniell cell convenient as a standard of elec- motive force	195
—, —, on a mechanical illustration of thermo-electric phe- nomena	118

	Page
Lodge, O. J., on a method of measuring the absolute thermal conductivity of crystals and other rare substances	201
—, —, on a modification of Mance's method of measuring battery resistance	145

M.

Machine, a small electrical	83
Magnesium sulphate, hydrated, separation of, from its solutions	65
Magnetic figures illustrating electrodynamic relations	333
Mance's method of measuring battery resistance, on a modification of	145
Mercury barometer, a sensitive	140
— cyanide as cryohydrate and cryogen	277
Metachromatic scale	112
Metals in the sun	314
Microphone, physical action of the	255
Millar, W. J., on the transmission of vocal and other sounds by wires	292
Morley, H. F., on Grove's gas-battery	212

N.

Nicol prism, interference fringes within the	185
--	-----

O.

Organic colloids, mixtures of	99
— crystalloids in aqueous solution	92
Orifices, the discharge of water from	325

P.

Perry, Prof. J., and Ayrton, Prof. W. E., on ice as an electrolyte	171, 199
Phenomena of induced electric sparks	102
—, thermo-electric, mechanical illustration of	118
Physical action of the microphone	255
— points connected with the telephone	224
Plateau's films, permanent	209
Polarization of electrodes in water free from air	15
— of heat	143
Potassium acetate, separation of ice &c. from solutions of	91
— and ammonium, mixed chlorides of, as cryohydrates and cryogens	6
— and sodium, mixed chlorides of, as cryohydrate and cryogen ..	6
— and sodium, mixed nitrates of, as cryohydrate and cryogen	5, 6
— bromide, anhydrous, separation of, from its solutions	63
— ferricyanide as cryohydrate and cryogen	275
— ferrocyanide as cryohydrate and cryogen	275

	Page
Potassium hydrate as cryogen	273
— iodide, anhydrous, separation of, from its solutions	63
— nitrate, anhydrous, separation of, from its solutions	60
— oxalate as cryohydrate and cryogen	276
— permanganate as cryohydrate and cryogen	273
— —, absorption spectrum of	344
— —, light reflected by	340
— —, reflection spectra of	342
— —, surface-colours of	341
— sulphate and ammonium chloride as a cryohydrate	13
— — and sodium chloride as a cryohydrate	12
— — and sodium nitrate, comparison between a mixture of, and of potassium nitrate and sodium sulphate as cryohydrates and cryogens	11
Preece, W. H., on some physical points connected with the telephone	224
Problems connected with the flow of electricity in a plane	24

R.

Radiation, case when exterior, is prevented	205
Rectilinear figures, electrical resistance of	30
Reflection spectra of potassium permanganate	342
Reflexion, conditions of total	188
Resistance-expression, electrical, for two poles	42
— measurements, battery, in general	145
Resonators, brass wind instruments as	261
Right-angled triangles, electrical resistance of	51

S.

Salt solutions and attached water	1, 53, 87, 271
— —, correlation between the boiling and glaciation of	69
Salts, mixed, as cryogens and cryohydrates	4
—, mixtures of, separation of ice from solutions of	74
Sector, circular, electrical resistance of a	40
Selective absorption	110
Silver and ammonium, nitrates of, separation of ice from solu- tions of	75
— cryohydrate, separation of, from its solution	66
— nitrate, anhydrous, separation of, from its solution	66
Soda hyposulphite as cryohydrate and cryogen	277
Sodium acetate, separation of ice &c. from solutions of	91
— and ammonium, mixed sulphates of, as cryohydrates and cryogens	9
— and hydrogen tribasic phosphate, separation of ice &c. from solutions of	88
— and potassium, mixed chlorides and mixed nitrates of, as cryo- hydrate and cryogen	5, 6

	Page
Sodium chloride, separation of, from its solutions	59
— and potassium sulphate as a cryohydrate	12
— fluoride as cryohydrate and cryogen	277
— iodide, further examination of	76
— nitrate and potassium sulphate, comparison between a mixture of, and of potassium nitrate and sodium sulphate as cryohydrates and cryogens	11
— nitrate, separation of ice &c. from solutions of	89
Solar chemistry, researches in	308
Sounds, transmission of, by wires	292
Sparks, electric, phenomena of induced	102
Spectra, five orders of	117
—, reflection, of potassium permanganate	342
Squares, electrical resistance of	51
Strip, electrical resistance of a	38
Strontium and barium, mixed nitrates of, as cryohydrates and cryogens	8
— hydrate as cryohydrate and cryogen	271
— nitrate, separation of ice &c. from solution of	90
Structural absorption	112
Subcryohydrate, separation of, from its solutions	59
Sun, metals in the	314
Surface-colours of potassium permanganate	341

T.

Tartaric acid in aqueous solution	94
Telephone: applications	228
— as a detector	226
— as a source of electricity	224
—, improvements in the	227
—, physical points connected with the	224
—, working the	227
Temperature, curves of	207
—, influence of, on the passage of air through capillary tubes ...	246
Thermal conduction through a cylinder inserted between metal rods..	203
— conductivity, absolute, of crystals and other rare substances ..	201
Thermoelectric currents, production of, in wires subjected to me- chanical strain	236
— phenomena, mechanical illustration of	118
Thompson, S. P., on some phenomena of induced electric sparks....	102
—, —, on the chromatic aberration of the eye in relation to the perception of distance	157
—, —, on interference fringes within the Nicol prism	185
—, —, on permanent Plateau's films	209
—, —, on magnetic figures illustrating electrodynamic relations.	333
Transverse absorption	111

	Page
Triangles, equilateral, isosceles, and right-angled, electrical resistance of	43, 46, 49, 51
Tunzelmann, G. W. von, on the production of thermoelectric currents in wires subjected to mechanical strain	236

U.

Unwin, Prof. W. C., on the discharge of water from orifices at different temperatures	325
Urea, nitrate of, as cryohydrate and cryogen	276

V.

Vocal sounds, transmission of, by wires	292
---	-----

W.

Water, attached, and salt solutions	1, 53, 87, 271
—, chromatic value of other media than	287
—, separation of, from crystalline solids in currents of dry air	281
—, the discharge of, from orifices	325
Wave-apparatus, a new form of, suitable for a lecture-room	21
Waves, two plane, apparatus to illustrate the interference of	182
Wedge, electrical potential in a	41
—, — resistance of a	35
Wind instruments, brass, as resonators	261
Wires, production of thermoelectric currents in, subjected to mechanical strain	236
—, transmission of sounds by	292
Woodward, C. J., on a new form of wave-apparatus suitable for the lecture-room	21
—, —, on an apparatus to illustrate the interference of two plane waves	182

Z.

Zinc acetate as cryohydrate and cryogen	277
— and potassium sulphate as cryohydrate and cryogen	274

PROCEEDINGS
AT THE
MEETINGS OF THE PHYSICAL SOCIETY
OF LONDON.
SESSION 1877-78.

Ordinary Meetings.

February 3rd, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following were elected Members of the Society :—

J. NORMAN LOCKYER, F.R.S.

Hon. Members : A. CORNU ; P. J. C. JANSSEN.

The following paper was read :—

“On Vortex Motion.” By Prof. OSBORNE REYNOLDS.

February 17th, 1877.

Prof. W. G. ADAMS, F.R.S., Vice-President, in the Chair.

The following was elected a Member of the Society :—

T. W. PHILIPS.

The following papers were read :—

“On Apparatus to illustrate Wave-motion.” By C. J. WOODWARD.

“On Galvanometers in the form of Lantern-slides.” By S. P. THOMPSON.

“On the Vapour-tension of Combined Water.” By Dr. F. GUTHRIE.

“On the Distribution of Electricity in Non-conductors.” By Dr. F. GUTHRIE.

March 3rd, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following were elected Members of the Society :—

P. LE NEVE FOSTER, M.A.; J. A. FLEMING.

The following papers were read :—

“On the Polarization of Heat.” By Prof. G. C. FOSTER.

“On an Arrangement of Thomson’s Galvanometer for showing Small Deflections to an Audience.” By LATIMER CLARK.

“On a Modified Form of the Holtz Machine.” By W. J. WILSON.

March 17th, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following was elected a Member of the Society :—

W. S. SEATON.

The following papers were read :—

“On the Stratifications in Vacuum-tubes.” By W. SPOTTISWOODE.

“On a Modification of Mance’s Method for determining the Resistance of a Galvanic Battery.” By O. J. LODGE.

“On the Theory of the Photographic Image.” By Capt. ABNEY.

April 14th, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following papers were read :—

“On a Portable Calorimeter.” By Dr. E. J. MILLS.

“On a New Half-prism Spectroscope.” By W. H. M. CHRISTIE.

April 28th, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following papers were read :—

“On Selective Absorption.” By W. ACKROYD.

“On the Composition of Rectangular Motions, and on a Method of Measuring the Velocity of Machinery.” By Prof. McLEOD.

May 12th, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following were elected Members of the Society :—

Capt. R. G. SCOTT, R.E.; Dr. FRANKLAND, F.R.S.; W. H. M. CHRISTIE, M.A., F.R.A.S.; Lieut. DARWIN, R.E.; Capt. ARMSTRONG, R.E.; H. F. MORLEY, B.A.; A. WEISS.

The following papers were read :—

“On the Achromatism of the Eye in reference to the Perception of Distance.” By S. P. THOMPSON.

“On the Acoustical Phenomena accompanying the rapid rotation of a Vibrating Tuning-fork.” By S. P. THOMPSON.

May 26th, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following were elected Members of the Society :—

W. T. THISELTON DYER, M.A., B.Sc.; Dr. H. DEBUS, F.R.S.; Lieut.-Col. CAMPBELL, of Blytheswood; Capt. G. SALE, R.E.; WILLIAM JACK, M.A.

The following papers were read :—

“On a Divided-Slit Spectroscope.” By Lieut.-Col. CAMPBELL.

“On Ice as an Electrolyte.” By Profs. AYRTON and PERRY.

June 9th, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following were elected Members of the Society :—

W. H. NORTHCOTT; L. J. WHALLEY

The following paper was read :—

“On the Interference Fringes in a Nicol’s Prism.” By S. P. THOMPSON.

June 23rd, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following papers were read :—

“On the Adaptation to Clifton’s Optical Bench of Melloni’s Apparatus, and on an Arrangement for showing the Interference of Light by Thick Plates.” By Prof. W. G. ADAMS.

“On the Electrical Diagnosis of Metals.” By Dr. GUTHRIE and W. ACKROYD.

November 3rd, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following was elected a Member of the Society :—

A. JESSEMAN.

The following papers were read :—

“On Experiments to determine the Exact Number of Vibrations of Tuning-forks by means of the Apparatus already exhibited to the Society.” By Prof. H. M’LEOD.

Exhibition of Artificial Gems recently prepared by M. Feil. By Dr. HUGGINS.

“On Ice as an Electrolyte.” (Continued.) By Profs. AYRTON and PERRY.

“On a Simple Apparatus for showing the Interference of two Plane Waves.” By Dr. F. GUTHRIE.

November 17th, 1877.

Dr. W. H. STONE, Vice-President, in the Chair.

The following paper was read :—

“On a Simple Form of Guard-ring Electrometer for Absolute Measurements.” By Prof. G. C. FOSTER.

December 1st, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following paper was read :—

Lecture on the Telephone. By Prof. A. GRAHAM BELL.

December 15th, 1877.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following were elected Members of the Society:—

J. W. CLARK; J. M. CAMERON; H. N. MOSELEY, M.A., F.R.S.;
The Rt. Hon. LORD RAYLEIGH, M.A., F.R.S.; H. T. WOOD; W. N.
STOCKER, M.A.; Prof. W. E. AYRTON; J. E. JUDSON, B.A.

The following papers were read:—

“On Permanent Plateau’s Films.” By S. P. THOMPSON.

“On the Colours exhibited by Vibrating Soap-films.” By SEDLEY
TAYLOR.

January 19th, 1878.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following were elected Members of the Society:—

Lieut. G. S. CLARKE, R.E.; J. F. ISELIN, M.A.; J. ANGELL; J. W.
RUSSELL, M.A.

The following papers were read:—

“On the Physical Theory of the Telephone.” By W. H. PREECE.

“On a Method of Measuring the Absolute Thermal Conductivity
of Rare Substances.” By Dr. O. J. LODGE.

Annual General Meeting.

February 2nd, 1878.

Prof. G. C. FOSTER, F.R.S., President, in the Chair.

The following Report of the Council was read by the President:—

The Council is again able to view with satisfaction the position
and prospects of the Society.

The number of Members has risen from 201 at the date of the
last Annual Meeting to 232 at the present time.

The papers and communications submitted to the Society have
been nearly as numerous as in 1876. In the past year, however,
the Society owes no less than nine of the thirty-five papers to the
energy of two of its Members; and although the Council is not un-
mindful of the value and interest of the subjects brought forward,
it would strongly urge that the continued success of the Society

must in a great measure depend on the active support of each individual Member.

The Society is aware that the Council have undertaken, with the sanction of his representatives, to publish a collected edition of the scientific papers of the late Sir Charles Wheatstone. The printing of the papers is now approaching its completion, and the Council has pleasure in communicating to the Society the following Report presented to them by the Committee charged with superintending the publication :—

*“ Report of the Committee for Reprinting Sir Charles
Wheatstone’s Papers.*

“The Committee have the satisfaction of reporting to the Council that this work is now nearly finished. Eighteen sheets are in type, and the remaining matter, amounting to three or four sheets more, is now in the hands of the printer.

“The Committee found much greater difficulty than they expected in obtaining copies of some of the papers ; and owing mainly to this circumstance the work has occupied a much longer time than it was expected to take. The Committee, however, hope to be able to issue the volume very shortly.”

It was resolved that a circular notice, embodying a proposal from the Council with reference to the translation of papers and monographs which have appeared in Foreign Journals, should be sent to each Member of the Society, and to certain other persons who might also afford valuable information and advice.

The subjoined Report has been presented to the Council in relation to the replies elicited by this circular, and is now communicated to the Society :—

*“ Report of the Committee on proposed Reprinting of
Scientific Papers.*

“The following circular was sent out to all the Members of the Physical Society, and to about 100 other scientific men selected from the list of the Royal Society :—

“DEAR SIR,—The Physical Society of London has appointed a Committee, consisting of the PRESIDENT Prof. G. C. FOSTER, Prof. W. G. ADAMS, and Dr. ATKINSON, to gather information and report upon a proposal for issuing to its Members translations from foreign languages of important contributions to Physical Science.

"It is thought that the Society might with advantage devote some portion of its funds to supplying its Members in this way with Papers which might not otherwise be easily accessible to them.

"It is not proposed that in the choice of Papers for translation the Committee should necessarily be limited to contemporary physical literature; but that, in addition to recent Papers distinguished for the novelty and importance of the results recorded in them, whether experimental or theoretical, or for the excellence of the methods described, attention should also be given to Memoirs, irrespective of the date of their publication, which have exerted a prominent and lasting influence on the development of Physics. Selections from Text-books, or other systematic works, in which some important subject is exceptionally well treated, might also be occasionally included.

"The Translations would be printed uniformly with the Proceedings of the Society, but would be paged separately, and, if the experiment were successful, would ultimately result in one or more volumes similar to 'Taylor's Scientific Memoirs.' The extent to which the scheme may be carried out will, however, naturally depend very greatly upon the amount of support it may receive.

"The Committee would be glad to be favoured with your opinion as to the utility of this undertaking, and more especially with any suggestions as to suitable materials for their selection.

"Please address any reply to Dr. ATKINSON, Portesbery Hill, Camberley, Farnborough Station.

"We are,

"Yours faithfully,

"G. C. FOSTER.

"W. G. ADAMS.

"E. ATKINSON.

"November 1877.

"Up to the present date about twenty replies have been received; with few exceptions they express decided approval of the general scheme indicated in the circular, and we have received several offers of pecuniary assistance towards carrying it out.

"The only decided objection that has been raised is one based on the idea that the scheme will not pay, and that any funds which the Society can spare for such a purpose would be better spent in promoting the acquisition of new knowledge by paying for original research. It may be replied to this that the scheme is not put forth as one likely to be self-supporting, but rather as a legitimate and useful object on which to spend some portion of the Society's funds; and that any money which the Society could devote to purposes of research would be a very insignificant addition to the funds already available for this purpose from other sources.

"Considering the replies as a whole, the Committee feel fully

justified in recommending the Council to proceed with the scheme; but the precise form which it should assume is obviously a matter calling for careful consideration.

"Some of those who have sent the most detailed replies to the circular have suggested undertakings on the part of the Society which, if they could be properly carried out, would unquestionably be of high value; but none of these suggestions appear to the Committee to be as practicable as the plan indicated in the circular.

"For example, it has been proposed that the Society should undertake the preparation and publication of a series of Tables of Physical Constants. Such a work would undoubtedly be of great value if prepared with sufficient care and knowledge, and on a sufficiently comprehensive scale. But it would require ampler funds than are at the disposal of the Society, at any rate for the present, and would involve a greater amount of personal labour and supervision than the Society can command for such a purpose.

"It has also been suggested that the Society should publish exhaustive digests of the work that has been done in connexion with special Physical Problems—such, for instance, as the determination of the velocity of sound, or of the mechanical equivalent of heat, or of the absolute unit of electrical resistance. In this case, again, the Committee, while fully recognizing the great utility which work of the kind proposed would possess, hardly see how it could be efficiently carried out otherwise than as an individual literary effort, which the Society would not have any special power of furthering.

"The plan of action suggested in the circular does not seem to the Committee to be open to these objections to the same degree; and an important point in its favour is the ease with which the scale of operations could be adjusted to the funds which the Society may from time to time be able to devote to this purpose.

"The Treasurer thinks that with its present number of Members the Society might under ordinary circumstances afford to spend about £50 a year in this way. The Committee estimate that for this sum from six to eight sheets of matter might be issued to the Members. It is probable, however, that owing to the considerable outlay incurred for registering the Society, and to the cost of re-printing Sir Charles Wheatstone's papers, the Society may not be in a position to spend much this year. But it must be remembered that these are not recurring expenses."

The Council propose to take action, in general accordance with the above recommendations, at as early a date as may be practicable.

On the 28th of April the Committee appointed to take measures for the legal Incorporation of the Society reported progress; and on the 9th of June a Special General Meeting was held to consider the changes in the Bye-Laws rendered necessary by the requirements of the Board of Trade. On the 23rd of the same month the amended Bye-Laws were finally approved by the Society. The papers have since been forwarded to the Board of Trade, and have been accepted by that Department without change, a result which the Council cannot but feel is in no small measure due to the valuable suggestions and carefully considered criticisms of two Members of the Society—Mr. CHANNELL LAW and Mr. FRANK CRISP.

The Board of Trade has recently granted to the Society a Certificate of Incorporation; and this General Meeting is held, as the law directs, within four months of the Registration of the Society.

The Council need hardly recall the advantages which accrue from Registration; but it would again point out that if this important step had not been taken the liability of the Members would have been unlimited, and the Society would have been unable to hold property or to recover debts.

The question of altering the time of meeting has again been anxiously discussed by the Council; and during the present year a formal opportunity will be afforded to each of the Members of expressing an opinion as to the desirability of a change.

The Council has determined to form the nucleus of a Library by expending a certain sum annually in the purchase of periodicals, and donations of books are invited. The thanks of the Society are already due to Prof. GUTHRIE for copies of the works of Boyle and of Bacon, and to Prof. REINOLD for a copy of Newton's 'Principia.'

Several foreign and other publications have also been received during the past year, and the thanks of the Society have been offered to the respective donors. Among these may be mentioned one from our distinguished Honorary Member M. CORNU, namely, a volume of the 'Annuaire de l'Observatoire de Paris,' containing a detailed account of his recent remarkable experiments for the determination of the velocity of light.

Last year the Council determined to put in force the section of the Bye-Laws which relates to Honorary Members. Although the youthfulness of the Society caused the Council to hesitate for a time before taking this step, all were convinced that the two distinguished men who were elected last year would appreciate close relations

with us, as both had shown their sympathy by reading papers at our Meetings. With regard to the two illustrious physicists whose names are submitted to you to day, the Council could not but feel that they might seek alliance with men to whom Honorary Membership is the only tribute of respect we are able as a body to offer.

The Council propose to avail themselves at an early date of their power to recommend, as an ex-officio Member of the Society, the President of the Physical Society of Paris.

Our grateful thanks are due to the Lords of the Committee of Council of Education not only, as heretofore, for permission to hold our Meetings in the Science Schools, but also for the loan of the Theatre of the South Kensington Museum on the occasion of Prof. Graham Bell's lecture. The application for the use of the Theatre was made on our behalf by Major Festing, R.E., to whom, as well as to the officers of the Museum, we are indebted for the excellent arrangements which contributed so largely to the success of the meeting.

The Treasurer presented the audited Balance-sheet, and the Society then proceeded to the election of the Council and Officers for the ensuing year, and for Honorary Members. Prof. S. P. THOMPSON and Mr. W. CONRAD COOKE were appointed Scrutators. The following gentlemen were declared duly elected:—

President.—Prof. W. G. ADAMS, M.A., F.R.S.

Vice-Presidents.—Dr. J. H. GLADSTONE, F.R.S.; Prof. G. C. FOSTER, F.R.S.; Prof. R. B. CLIFTON, M.A., F.R.S.; W. SPOTTISWOODE, LL.D., F.R.S.; W. H. STONE, M.B., F.R.C.P.; Sir WILLIAM THOMSON, LL.D., F.R.S.

Secretaries.—Prof. A. W. REINOLD, M.A.; W. CHANDLER ROBERTS, F.R.S.

Treasurer.—Dr. E. ATKINSON.

Demonstrator.—Prof. F. GUTHRIE, Ph.D., F.R.S.

Other Members of Council.—Capt. W. de W. ABNEY, R.E., F.R.S.; Prof. W. F. BARRETT, F.R.S.E.; Major F. R. FESTING, R.E.;

W. HUGGINS, D.C.L., F.R.S.; Prof. A. B. W. KENNEDY, C.E.; O. J. LODGE, D.Sc.; Prof. H. M'LEOD; The Earl of ROSSE, D.C.L., F.R.S.; Prof. W. C. UNWIN, B.Sc.; R. WORMELL, D.Sc.

Honorary Members.—Prof. HERMANN LUDWIG FERDINAND HELMHOLTZ; Prof. WILHELM EDUARD WEBER.

After the names had been announced from the Chair, votes of thanks were proposed:—to the PRESIDENT; to the Lords of the Committee of Council on Education; to the DEMONSTRATOR, TREASURER, and SECRETARIES.

THE TREASURER IN ACCOUNT WITH THE PHYSICAL SOCIETY, FROM DECEMBER 31ST, 1876, TO DECEMBER 31ST, 1877.

12

PROCEEDINGS OF THE PHYSICAL SOCIETY.

Dr.	£	s.	d.	Cr.	£	s.	d.
Balance in Bank December 31st	44	4	1	Purchase of £100 5 per cent. Midland Preference Stock	123	7	3
" due by Treasurer	22	19	11	Deed Box	1	0	1
Entrance-Fees	25	0	0	Reports of Meetings	16	2	0
Subscriptions for 1875	3	0	0	Messrs. Taylor and Francis:—			
" 1876	10	0	0	Printing Proceedings &c., part ii. vol. ii....	38	10	6
" 1877	106	0	0	" " part iii. vol. ii....	19	12	6
" 1878	5	0	0	Separate copies	3	14	6
" 1879	1	0	0	Postage and addressing	1	14	6
Compositions	120	0	0	Miscellaneous Printing	17	6	2
Dividends on £400 4 per cent. Furness Deben- ture Stock, less Income Tax, 4s.	15	16	0	Mr. Richardson, of Greenwich:—			
Dividends on £200 5 per cent. Midland Pre- ference Stock, less Income Tax, 2s. 6d.	9	17	6	Miscellaneous Printing	1	16	0
Sales of Everett's C.G.S.	20	14	0	Chapman: Attendance at Meetings.....	3	15	0
Balance due to Treasurer	6	10	3	Incidental Expenses	1	5	3
				Petty Cash:—			
				Mr. Roberts	1	3	0
				Mr. Reinold	2	17	0
				Dr. Atkinson	1	10	1
				Loss on Cheque	5	10	1
				India-rubber Company for expenses of Prof. Bell's Lectures	0	0	7
				Balance in Bank	1	19	0
					154	8	4
					<u>£390</u>	<u>1</u>	<u>9</u>

We have examined the above Account, and find that there is due to the Treasurer an amount of Six Pounds, Ten Shillings, and Threepence.

London, January 28th, 1878.

ROBT. J. LECKY, }
CARLTON LAMBERT } Auditors.

PROPERTY ACCOUNT. PHYSICAL SOCIETY.

ASSETS.	£	s.	d.
Subscriptions due	43	0	0
£400 4 per cent. Debenture Stock Furness Railway at 103	412	0	0
£300 5 per cent. Preference Stock Midland Railway at 123	369	0	0
Stock of Everett's C.G.S.	10	0	0
Cash in Bank	154	8	4
	£988	8	4

LIABILITIES.	£	s.	d.
Expenses of Registration	75	0	0
Expenses of the Reprint of Sir C. Wheatstone's papers	200	0	0
Subscriptions in advance	6	0	0
Due to Treasurer	6	10	3
Balance	700	18	1
	£988	8	4

We have examined the above Account, and find that there was a balance of Seven Hundred Pounds, Eighteen Shillings, and One Penny in favour of the Society on the 31st of December, 1877.

London, January 28th, 1878.

ROBT. J. LECKY,
CARLTON J. LAMBERT.

